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Siboga-Expeditie
IV

THE FORAMINIFERA OF THE SIBOGA EXPEDITION

BY

J. HOFKER

PART I

Families TINOPORIDAE, ROTALIIDAE, NUMMULITIDAE, AMPHISTEGINIDAE

With 38 plates and 11 textfigures

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INTRODUCTION.

When studying the literature on Foraminifera, one may be astonished at finding how little is known about the bionomics of that group of Protozoa. Most of the works dealing with Foraminifera are only systematical, geographical or geological, and only a few give some notes on the lives of this important group. But how to give an exact account on systematics, when ignoring the polymorphism of Foraminifera? There is another fact which draws our attention: how many authors have published long articles on Foraminifera who lacked every insight into biological questions. In this way geological records on Foraminifera mostly bristle with mistakes.

As there is but little known about the protoplasm of Foraminifera, systematics are only based upon the structure of the shell. It is obvious, that as already the shell forms but a part of the creature by which it was built, this shell must be known in detail, if one wants to base a classification on it. There are, however, but few species of foraminiferal shells known in all details, and so a classification will often cause very great mistakes [1]). It was therefore that I looked for new methods to study the shells; besides I was able to throw some light upon the bionomics of these interesting animals. As I already described in a short paper [2]), I pointed out the probability that in most populations of a single species three forms must be distinguished, two of them being extremely differentiated ♀ and ♂ gamonts, of megalospheric form, the third, the microspheric form, forming megalospheric agametes. At first these agametes are not differentiated into ♀ and ♂ gamonts, but after several asexual reproductions the differentiation gradually takes place. In a sample one may thus distinguish the two megalospheric kinds of gamonts, all intermediate stages between these two extremes, and the microspheric agamonts. I called this phenomenon in my further investigations "trimorphism", and I tried to find it in all the species I studied. Possibly I have made some errors, but in most cases I could easily distinguish the three forms. Sometimes forms, considered by other authors as different species, are here combined into one species by means of the trimorphism. Mostly the two gamonts can be distinguished easily, one showing a small, the other a large megalosphere [3]). Another peculiarity, already mentioned by SCHLUMBERGER, is shown by the microspheric generation. In most

1) In respect to the structure of the shell, I must point out that the largest opening (or openings) in each chamber, found in perforated as well as in imperforated shells, and often indicated by "mouth", must be called the foramen (or foramina), whereas the narrow perforations of the walls in perforated shells have always been mentioned in this work as "pores".

2) HOFKER, J., On Heterogamy in Foraminifera (Tijdschr. d. Ned. Dierk. Vereen., 2, vol. XIX, p. 68—70, 1925).

3) In the resumed characteristics of the species I have used the letters A_1, B and A_2 to designate the three forms. As the microspheric form has been distinguished by SCHLUMBERGER and MUNIER-CHALMAS as Forma B, I have also used B for this form. The form with the smallest megalosphere has been called A_1, that with the larger first chamber A_2.

cases this form possesses the most primitive characteristics; this fact is very important from a systematical point of view.

The following methods were used by me when studying the shells:

1. Slides. They have been prepared by means of an amarylstone, used for common purposes. The stone was made wet by water or, in some cases, by xylol, and very beautiful slides can be prepared with it.
2. Total decalcifying by means of acetic acid.
3. Microtomic sections, after total decalcifying, coloured by means of haematoxyline and eosine.
4. Canadabalsam-impregnation. This method, which gives very beautiful results, when the inner structure of the shell is studied, has been described by me in the introduction to my publications on the Foraminifera of the senonian chalk of Maestricht [1]).

I will give here a short account of this method: slides are made in the usual way; they are mounted in boiling canadabalsam on a glass, and after the balsam has become hard, the slide is put into a vessel containing acid, and thus the chalk is solved. The remaining canadabalsam, filling up even the finest pores, gives a very good idea of the canalsystem, the shape of the chambers, the place of the foramina and the pores.

The same results may be obtained by means of a method, described by MOEBIUS [2]), but that method is not so easy and can only be used with very thin slides.

As the material is more than twenty years old, but little can be said about the conservation of the protoplasm. Only some samples, gathered by L. J. TOXOPEUS at Buru, dated 1925, were very well preserved and are also mentioned here.

It was a great loss that the bottom samples collected by the soundings of the expedition, had not been preserved by Prof. BÖGGILD after his investigations. Fortunately most of them had been looked through for larger Foraminifera; the samples themselves would of course have yielded more of them by renewed sifting especially with respect to the smaller forms. This collection has been augmented and completed by material gathered from bottom samples brought up by trawlings, dredgings, by anchor, or found on coralreefs, lithothamnium banks or on algae.

Some other samples collected by cable-ships ("De Telegraaf", "van Gogh") give some idea about the very abundant Foraminifera in tropic seas; the results of these dredgings will also be published here. In these circumstances the geographical distribution of the species has not much value. So only in a few cases geographical questions will be mentioned.

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1) HOFKER, J., Die Foraminiferen aus dem Senon Limburgens, I. (Natuurhist. Maandblad, Maestricht, vol. 15, pt. 2, p. 14, 1926).
2) MOEBIUS, K., Beiträge zur Meeresfauna der Insel Mauritius und der Seychellen, Foraminiferen, p. 82, 1880.

Family TINOPORIDAE.

Test free or attached, in the microspheric forms composed of a short, rotaliform spiral, followed by more cyclically arranged chambers, in the megalospheric forms either beginning with an irregular, very short spiral, or with a very conspicuous set of chambers, forming a group of chambers, in shape very much like a raspberry. In its most developed form this "raspberry" consists of a large proloculum, followed by a chamber of nearly equal diameter; the third chamber, the axis of which crosses the junction between the former two chambers, is kidney-shaped and in most cases very large. These four chambers are surrounded by a clew of others. This embryonic apparatus in most cases is followed by another kind of chambers, generally growing in a single plane, and characterised by the possession of four foramina each, instead of two; with these four foramina each chamber communicates with two preceding and two following chambers. The chambers have coarse, but short pores, which only communicate with other chambers, when there are layers of a third kind of chambers, building rows more or less vertically directed on the median plane of chambers. In some genera the foramina grow out into siphonal hollows which form an important part of the shell. In one genus (*Homotrema*) the porous chambers are reduced and the siphonal hollows form the whole shell. No trace of an interseptal canalsystem is found in this family, though in most cases the walls are double.

There may be some probability that the most primitive genus of this group, *Planorbulina*, with its synonym *Linderina*, which has been found in all strata of the tertiary epoch, descends directly from the genus *Cymbalopora*, with its rotalide first coils and its cyclically arranged later chambers. In that case the first development falls in the cretaceous period. That must be really the case, for I myself found a low organised species of *Polytrema* in the upper senonian chalk of Maestricht. There are, however, just in foraminiferal research, very few reasons to search for ancestral forms of whole groups, as I believe that most larger groups of Foraminifera find their origin in forms which lacked calcified shells, so that these ancestrals cannot be found fossilised. We can only state a similar plane of growth of the shells in larger groups of Foraminifera and then we conclude that there may be some closer relation between these forms.

Within this group of Foraminifera with chalk shells it may in some cases be easy to give an idea of the relation of the species, and the evolution within this group may be traced in the same way. But it is also quite possible that some of the genera of the group, though descending from the same ancestral form, have had their evolution before they got chalk shells.

In this case only the structure of the earlier coils of chambers will give us an idea of their relation, but we can give no clear description of their evolution. In this way we can establish families and subfamilies of Foraminifera, and we can group the genera and species belonging to these families with more or less certainty so that a genus is allied with, or even comes from the next.

Though there are some strong reasons to believe the genus *Planorbulina* to be the ancestor of more than one higher organised species, there are others which certainly descend from the same ancestor as *Planorbulina* itself. It is also possible that *Planorbulina* (= *Linderina*) owes its primitive characteristics to its epibiontic life, *Linderina* not being found earlier than Eocene strata, whereas the higher organised *Polytrema* in its most primitive form lived in the cretaceous period. But, as I have already stated, no certainty can be given about these points. If we suppose *Planorbulina* to be the most primitive form of the group, the genus *Sporadotrema* comes from this ancestral type, probably with "*Gypsina*" *rubrum* as a link. In *Sporadotrema* the intention of building more than one plane of chambers first appears in the cretaceous *Sporadotrema* (= *Omphalocyclus*) *macroporum* from Maestricht, and at the same time the stoloniferous foramina develop [1]).

A second series, probably with *Planorbulina* in the centre, moves towards the *Polytrema*-group, with its mostly horizontal layers of irregular chambers and its inclination towards stolon building, having its climax in the genus *Homotrema*. Probably some species with chambers possessing four foramina of the *Gypsina*-group belong to this series. There are other "Gypsinae", which are looked upon as descending from some *Discorbina*; I believe that the whole genus *Gypsina* better had to be swept away, for a more careful examination of some of these Gypsinae taught me that this genus is a very heterogeneous one. Some of these Gypsinae, viz. the attached ones with chambers with more than two foramina each, belong to the *Polytrema*-series; others however (viz. *Gypsina globulus*) have to be considered as forming a third series of TINOPORIDAE, the allies of *Tinoporus*. This very large group of very important genera is not the same as that which generally goes by this name. With this group CHAPMAN [2]) classes the genera *Tinoporus* (the species "*Tinoporus baculatus*" however is, as we shall show later on, a *Calcarina*-like species with canalsystem, just as "*Baculogypsina*"), *Gypsina* (which is right in so far as it deals with *G. vesicularis*, *G. globulus* and their allies, but not with respect to *G. inhaerens* for instance), *Miogypsina* (perhaps right) and *Polytrema* (which is not quite right, as we have mentioned above). CUSHMAN dropped the genus *Tinoporus* itself, and thought that all species, mentioned by authors under this name, really belonged to the genus *Baculogypsina*; but we will show that there are real *Tinopori* s. s., whereas *Baculogypsina* belongs to another group of the ROTALIDAE.

But a very important group of Foraminifera must certainly be put in this group around the genus *Tinoporus*, viz. the ORBITOIDAE, as I already pointed out in my work on the Foraminifera of the Senonian of Limburg [3]).

As we shall show, the genus *Tinoporus* possesses a typical planorbulinine embryonic

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1) There can be no doubt that "*Omphalocyclus*" belongs to this group; and DOUVILLÉ must be wrong when he suggests that "*Omphalocyclus*" comes directly from *Siderolites* (1921, p. 211): the latter is a rotalide genus with a well-developed canalsystem.

2) CHAPMAN, F., The Foraminifera: an Introduction to the study of the Protozoa, London, 1902.

3) HOFKER, J., Die Foraminiferen aus dem Senon Limburgens, III. (Natuurhist. Maandblad, Maestricht, vol. 15, pt. 4, 1926).

apparatus, followed by a thick clew of planorbulinine chambers, while this clew is succeeded by the rows of secondary chamberlets.

In the genus *Orbitoides* (and also in its relations *Miogypsina*, *Lepidocyclina*, and probably in *Orthophragmina* too) the embryonic apparatus shows the typical planorbulinine characteristics. Even the most primitive Orbitoid, *O. Tissoti*, shows the raspberry-shaped embryonic apparatus of megalospheric generation, though the first four chambers have the same diameter, as is the case in the primitive *Planorbulina*; *O. Tissoti* seems to be a *Planorbulina* with developed secondary chamberlets [1]). In some Orbitoids the mediane layer of chambers in every respect resembles a *Planorbulina*, but in others each chamber communicates with the next by means of no more than one foramen and so it may be the case that some Orbitoids possess much more than four foramina in each chamber. These mediane chambers communicate with the lateral rows of chambers only by means of pores; in this way we must regard these lateral chambers as the hollows between the semilunar thickenings of the outer walls of *Planorbulina larvata*, closed by a porous wall. In the same way the lateral chambers of *Arnaudiella* [2]) and *Baculogypsina*, in the subfamily of the Rotalinae, arise. So we can understand DOUVILLÉ's mistake of placing these Rotalinae at the base of the series of orbitoid species. The mediane plane of chambers of the Orbitoids corresponds with the irregular clew of chambers in the *Tinoporus*-species. The lateral chambers of *Orbitoides* and the secondary chamberrows of *Tinoporus* are so exactly alike, that it is impossible to distinguish them. DOUVILLÉ (1906) has already suggested that *Polytrema*, *Orbitoides*, *Gypsina* and *Baculogypsina* (must be *Tinoporus*) probably had the same origin (p. 601): "Il est possible du reste, que ce genre (*Orbitoides* aut.) soit hétérogène et ait des origines multiples. Ainsi, comme l'à très bien remarqué SCHLUMBERGER, l'*O. gensacica* présente à son centre un noyau polycellulaire qui rappelle tout à fait un jeune *Polytrema miniaceum*, de sorte qu'on devrait le considérer comme ayant une origine commune avec ce dernier genre.... Enfin, dans *Gypsina* et *Baculogypsina* il n'y a plus de loges équatoriales, mais un simple empilement des chambres tout autour du centre; celles-ci correspondent aux chambres latérales des Orbitoïdes; au centre, SCHLUMBERGER signale des loges embryonnaires disposées comme dans *Globigerina*" [3]).

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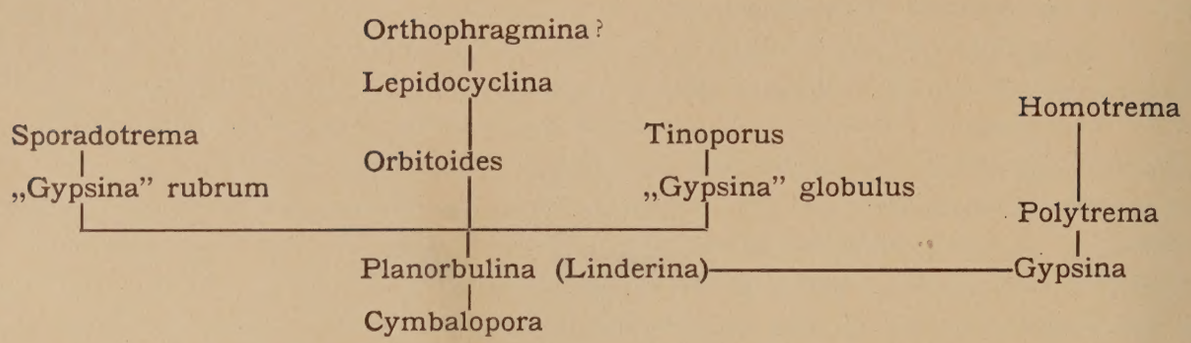
1) In this respect I am obliged to contradict Mr. H. DOUVILLÉ, when he says (1915, p. 664; 1921, p. 211), that the embryonic apparatus of *O. Tissoti* shows us "que les Orbitoïdes seraient ainsi des Protozoaires tout à fait exceptionnels, puisqu'ils seraient en réalité quadricellulaires", the apparatus arising by "une double division par caryocinèse de la cellule primitive", and forming "quatre cellules ayant chacune leur noyau distinct". Firstly no celldivision at all takes place when a Foraminiferum builds a new chamber; secondly the chambers, even those of the embryonic apparatus altogether form a single cellule; and thirdly a young megalospheric individuum possesses only one nucleus in its protoplasm, even if, as is the case in microspheric individuals in earlier stages the nucleus divides itself; but when an individual grows never real caryokinese takes place. All further considerations of DOUVILLÉ about the development of the "nucléoconque", as they are mostly based on the same mistakes, are therefore of no importance. Thus I stated in *Orbitoides* (1926) that all stages of so-called development will be met within a single species and are due to trimorphism. The development of the embryonic apparatus, though of some importance with respect to the systematic arrangement of families, is of no value with respect to genera or species. I emphasize this statement which is sufficiently demonstrated in the species in this work, as often genera and species are based only upon differences in embryonic apparates (see for example the classification of the Lepidocyclinae in VAUGHAN 1924, p. 794).

2) *Arnaudiella*, which is supposed to have arisen from *Calcarina calcitrapoides*, surely possesses a typical rotaline canalsystem. *Orbitoides* however, even lacks every trace of such a system, and CARPENTER's view on this point must be regarded as a mistake (1862, p. 302, Plate XX, fig. 5, 6, and 2).

3) With regard to the genus *Simplorbites* (DOUVILLÉ, 1921, p. 210) we may compare this genus with some specimens of *Orbitolites* and of *Cycloclypeus*, and other Foraminifera which have been called by RHUMBLER (1902) "Univalente Doppelschalen". I am going to show, when dealing with the genus *Cycloclypeus*, that these forms with more than one embryonic apparatus show, just as is the case in *Orbitoides gensacica*, a kind of gigantism.

Scheme of the TINOPORIDAE.



I. Genus **Planorbulina** d'Orbigny.

Test adherent; early chambers coiled in microspheric specimens of the higher species such as *P. larvata*, but in all forms in the lower organised species, such as *P. mediterranensis*. Chambers in a single layer; later chambers possessing four instead of two foramina each; this is the cause of the somewhat cyclical growth of these chambers. Each new chamber is connected with the two adjacent chambers of the nearest, previously formed series. Pores always coarse, never forming communication with other chambers.

It is possible that this genus is closely allied with *Cymbalopora* [1]), thus forming an intermediate stage between the higher forms of the family of the TINOPORIDAE and lower forms such as *Discorbina*.

1. *Planorbulina larvata* Parker and Jones. Plates I and II.

Planorbulina vulgaris d'Orbigny, var. *larvata* Parker and Jones, Ann. Mag. Nat. Hist., ser. 3, vol. 5, 1860, p. 294.

Planorbulina larvata Parker and Jones, Philos. Trans., vol. 155, 1865, p. 379, Pl. 19, figs. 3*a*, *b*. — H. B. BRADY, Rep. Voy. Challenger, Zoology, vol. 9, 1884, p. 568, Pl. 92, figs. 5, 6. — CUSHMAN, Bull. 71, U. S. Nat. Mus., pt. 1915, p. 27, Pl. 8, fig. 2. — CUSHMAN, Prof. Paper Geol. Survey U. S. A. 133, 1923, p. 39, Pl. VI, figs. 7, 8. — CUSHMAN, U. S. Nat. Mus., Bull. 100, vol. 4, 1921, p. 310. — HERON-ALLEN and EARLAND, Zool. Soc. London, Trans., vol. 20, p. 706, 1915. — CHAPMAN, Introd. Foram., 1902, p. 219, Pl. 12, fig. F. — CHAPMAN, Proc. Roy. Soc. of Victoria, vol. XXII, New series, P. II, 1910, p. 284.

Linderina Brugesi Schlumberger, Bull. S. Géol. France, ser. 3, vol. 21, 1893, p. 118—120, textfigs. 3—8, Pl. III, figs. 7—9. — PROVALE, Revista Ital. di Palaeont., 1909. — OSIMO, 1908, Rev. Ital. di Pal. XIV, p. 38—39, Pl. III, figs. 9—12, Pl. II, figs. 1—5. — RUTTEN, Nova Guinea, Résultats de l'Exp. Scientif. néerlandaise à la Nouvelle Guinée, 1914, p. 45—46, Pl. VII, fig. 3. — BULLEN NEWTON and HOLLAND, Ann. Mag. Nat. Hist., ser. 7, vol. III, p. 262, 1899.

This very remarkable and important species occurs in the following Siboga-Stations:

Stat. 77. 3° 27′ S., 117° 36′ E. 59 m.
Stat. 99. 6° 7′.5 N., 120° 26′ E. 16—23 m.
Stat. 166. 2° 28′.5 S., 131° 3′.3 E. 118 m.
Stat. 204. 4° 20′ S., 122° 58′ E. 75—94 m.
Stat. 260. 5° 36′.5 S., 132° 55′.2 E. 90 m.
Stat. 289. 9° 0′.3 S., 126° 24′.5 E. 112 m.

1) CHAPMAN, F., The Foraminifera: an introduction to the study of the Protozoa, 1902, p. 214: "*Cymbalopora*, especially the outspread modifications, shows some relationship with *Planorbulina*".

Short characteristics of the genus:

A_1. Large specimens attaining a diameter of 3 mm. Test attached, discoidal or somewhat concave. Central portion covered with irregularly thickened walls and sutures. At the periphery the chambers are irregularly shaped. Initial chambers a short, somewhat irregular coil.

B. Very difficult to distinguish from forma A_1. Only the chambers of the periphery are more regularly shaped. They form lips at their foramina, more distinct than is the case in forma A_1. First set of chambers a close-coiled spiral.

A_2. Externally not to be distinguished from forma A_1, but the first chambers form a "raspberry".

Three forms have been met with, the inner structure of which seems to me to be of enormous importance with respect to the fact that it will give us a better insight into the relationship of higher organised species, such as *Orbitoides*, *Tinoporus*, *Polytrema*, etc.

The microspheric form differs only from the megalospheric one by a somewhat compact form of the chambers at the periphery of the shell (Pl. I, fig. 5; Pl. II, figs. 1, 4). The first chamber, with a diameter of about 30 μ, is followed by a short spiral of rotalide chambers, which show only one foramen by which they communicate with each following segment. This short spiral of about two convolutions is followed by a somewhat cyclical growth of the chambers. At first the chambers are irregularly arranged round the first coils, but afterwards they form distinct rows running straight to the periphery; in the microspheric form however these rows are not very clear and the whole organism therefore is often irregularly shaped.

One of the two megalospheric forms cannot be distinguished externally from the microspheric one. The only difference lies in the first chambers, which build up an irregular heap (Pl. II, fig. 7), in which one may distinguish a spiral with some connivance. The first chamber possesses a diameter of about 45 μ.

The third form (Pl. I, figs. 1, 3, 4), likewise megalospheric, begins with a much larger proloculum of about 85 μ; three other chambers surround this first chamber, not in a spiral, but forming with the first an embryonic apparatus known as the raspberry-type (Pl. II, figs. 3, 6). These four chambers are equal in size, and are directly followed by the typical rows of chambers. These chambers are somewhat higher than those in the microspheric form, and at the periphery some of them project, making the surface much more irregular.

When we study a canadabalsam-preparation of the test, we state a very peculiar arrangement of the chambers (Pl. II, figs. 8, 10). Each chamber shows four foramina, two of which project to the centre of the shell and communicate with two chambers of the next rows, but are a little more towards the centre of the shell, and the two other foramina project to the periphery of the shell and communicate with two chambers of the next rows, but lie a little more towards the periphery of the shell. This arrangement of the secondary chambers is always found in those Foraminifera, in which the first chambers of one of the megalospheric forms show the raspberry-type. Therefore I am sure that these Foraminifera form a natural group, in the centre of which lies *Planorbulina larvata*. Dorsally and ventrally the chamberwalls

are perforated with very coarse pores, but never do the chambers themselves communicate with each other by means of these pores. These walls are thickened, especially in the older parts of the shell, by fine layers of chalk-substance, and often buds of chalk are built at the sutures between two chambers, so as to form the beginning of pillars, so well-known in *Orbitoides* and *Tinoporus*.

No trace of a canalsystem can be found. The apertures of the outer chambers are lipped (Pl. II, fig. 9).

As *Planorbulina larvata* is a typical, if not very common, inhabitant of shallow coral reefs and coral sands, it has been met with in most tropical seas. The geological distribution of this species is much more interesting. As CHAPMAN (1902, p. 219) already has pointed out, SCHLUMBERGER's *Linderina* may belong to the genus *Planorbulina*. RUTTEN (1914) says p. 45: "Die von SCHLUMBERGER aufgestellte Gattung *Linderina* gleicht in ihrem allgemeinen Bauplan den Cycloclypeen, unterscheidet sich aber sehr wesentlich von diesen durch den Mangel doppelter Septa und eines Kanalsystems in der Wand. Ich verstehe deshalb nicht, weshalb G. OSIMO diese Gattung in der Nähe der Orbitoiden stellen konnte, da sie durch ihre einfache Wandstruktur und ihre groben Poren weit eher in die Verwandtschaft der *Planorbulina larvata* gehört". The latter consideration is very true indeed, but we must here point out, that the genus *Cycloclypeus* does not bear any relation to *Orbitoides*, that *Orbitoides* does not possess a canalsystem, that most walls of *Planorbulina larvata* are really double and that the constitution of the chalk walls is not of any importance as a systematic characteristic; only the shape of the primary chitinous walls is of some value with regard to that.

SCHLUMBERGER's *Linderina Brugesi* and OSIMO's *L. Paronai* have been found in Eocene deposits; other species, such as Linderinae found by RUTTEN and by PROVALE (1909), occur in the Miocene.

SCHLUMBERGER's description (1893) and his figures (Pl. III, figs. 7—9), and even more those of OSIMO (1908, p. 14, Pl. II, figs. 1—5) and PROVALE (1909, Pl. III, figs. 9—12) show, that all these Linderinae belong to one and the same species and are but local varieties; this species however must be identical with *Planorbulina larvata*. This is CUSHMAN's view when describing the same fossil (1923) and also CHAPMAN's (1910, p. 284).

II. Genus **Gypsina** Carter.

Though at first I was inclined to drop this genus-name from my nomenclature, after a careful examination of the Siboga- and other specimens I came to the conclusion, that it would be better to keep this name, but in a more limited sense than it is used by other authors. Under the genus *Gypsina* we must gather all those forms with typical planorbulinine embryonic chambers, with later chambers mostly growing without any regularity, but with a tendency to form radiate rows. These chambers show thick walls with a smooth surface, coarsely but very regularly porous. No canalsystem is developed; the chambers always form more than one layer; they communicate with each other in the same layer by means of round foramina, in some cases showing the regular arrangement as is the case in *Tinoporus*; the chambers of different layers communicate with each other by means of pores.

This genus includes the species: *Gypsina inhaerens* and *G. vesicularis* [1]).

The other species must be looked upon as to belong to other genera. As I will show further on, the species "*Gypsina*" *rubra* d'Orb. belongs either to *Planorbulina*, showing a single layer of chambers, or it is a simple form of the genus *Sporadotrema*.

"*Gypsina*" *globulus* on the other hand must be named *Tinoporus*, because of its typical arrangement of the chambers in rows. Here lies the — somewhat indefinite — line between the genera *Gypsina* and *Tinoporus*.

2. *Gypsina vesicularis* (Parker et Jones). Plate III.

Orbitolina vesicularis Parker and Jones, Ann. Mag. Nat. Hist., 1860, n° 3, ser. 3, vol. V, p. 31, n° 5.
Tinoporus laevis Brady, Trans. Linn. Soc. (London), 1864, vol. XXIV, p. 470, Pl. 48, fig. 17.
Gypsina vesicularis Carter, Ann. Mag. Nat. Hist., 1877, ser. 4, vol. XIX, p. 173; BRADY, Challenger Report, 1884, p. 718, Pl. CI, fig. 9—12; EGGER, Abh. Kgl. bayer. Akad. d. Wiss., 1893, II. Cl., vol. XVIII, pt. 2, p. 382, Pl. XIV, fig. 20—23; CHAPMAN, Journ. Linn. Soc., London (Zoology), 1900, vol. XXVIII (1902), p. 198, Pl. XIX, fig. 12; CHAPMAN, Journ. Quekett Micr. Club, 1907, ser. 2, vol. X (1909), p. 140; HERON-ALLEN and EARLAND, Proc. R. Irish Academy, 1913, vol. XXXI, p. 140, Pl. XIII, fig. 11; HERON-ALLEN and EARLAND, Trans. Zool. Soc. of London, 1915, vol. XX, pt. XVII, p. 726—727; HERON-ALLEN and EARLAND, Brit. Mus. Nat. Hist. ("Terra Nova") 1922, Zoology, vol. VI, n° 2, p. 221.

Most striking characteristics:

Test attached, convex. Exterior marked by an irregular network of raised chamberwalls. Pores coarse. Chambers internally irregularly heaped, showing tendency to grow in rows vertical on the surface. First chambers of forma A_2 a raspberry.

There are but few specimens found in the Siboga-samples, from Station 152 (Wunoh-bay, N. W.-coast of Waigeu island, depth 32 m.). They are very typical, and all of megalospheric form. Most of them are of the type of *Gypsina vesicularis* var. *monticulus*, but it is very probable that the other varieties mentioned by CHAPMAN are nothing but forms due to trimorphism [2]).

The specimens were found attached to *Halimeda* (fig. 3); they have the shape of little hills with a somewhat outspread base. This base in older specimens is formed by lengthened radiating chambers (fig. 4). The surface of the hill shows irregular chamberlets with smooth, coarsely porous walls and somewhat protruding thick sutures (figs. 1 and 2).

When the shell is loosened from the alga, the lower surface shows the same aspect as the upper one, the little chambers also having porous walls. On the lower one the embryonic chambers are not to be seen, three or four layers of flat chambers separating them from the surface of the algue. So it is sure that before the attachment the shell must have been in a

1) I can say nothing about *G. plana* Carter, as no embryonic apparatus has been studied yet. Though Miss LINDSEY gives a detailed study on this species (On *Gypsina plana* Carter and the relations of the genus, Trans. Linn. Soc., ser. 2, Zool., vol. XVI, 1913, p. 45—51), this apparatus has not been found by her. There are some other remarkable facts in her study. The thin walls and high shape of the chambers, when seen in transverse section, must be paid special attention to. LINDSEY says, that the chambers communicate by no other openings than the pores of the walls, no foramina having been found. This must be a mistake. Firstly no Foraminifera without foramina have ever been found, and secondly on her figures 4 and 5 foramina have been clearly photographed. One must pay attention to the fact, when reading Miss LINDSEY's work, that she described the "pores" as "foramina" (see our "Introduction").

2) CHAPMAN, F., Foraminifera from the Lagoon at Funafuti; 1900 [Journ. Linn. Soc., London (Zool.), vol. XXVIII (1902).]

free-living state, forming all around the embryonic chambers layers of chambers, just as is the case in *Tinoporus*. These embryonic chambers show the ordinary planorbulinine shape (figs. 5 and 8), beginning with a globular chamber of about 100 μ diameter, surrounding the first. The only difference between this embryonic apparatus and that of true *Tinoporus* is the arrangement, as they are lying in a single plane. This is probably a primitive characteristic. The chambers communicate by the coarse pores as well as by means of foramina (fig. 6). In older specimens there is a tendency to grow out into radiating rows, thus giving rise to the *Tinoporus* shape of arrangement of chambers (fig. 9).

III. Genus **Tinoporus** Montfort.

There has been a great confusion, whether some tropical and subtropical forms of Foraminifera, with a test composed of numerous chambers, the exterior being areolated or reticulated, belong to this genus or to *Gypsina* Carter or allied genera (*Aphrosina* Carter, *Thalamopora* Roemer, *Polytrema* Risso). In the discussion on *Tinoporus baculatus* we shall show that BRADY did not base his generic description on a true *Tinoporus*, but on other genera, as there are *Baculogypsina* Sacco and *Siderolites* Lamarck. So BRADY's descriptions of this genus can no longer be maintained, and a new description of the genus *Tinoporus* is necessary.

As *Tinoporus baculatus* and *T. Floresianus* are the only two species of the Siboga-material, I was at first inclined to give the characteristics of these species also to the whole genus, especially as in the literature on this subject no other true *Tinoporus* has been mentioned than *Tinoporus baculatus*, which will be discussed more amply below (see *Tinoporus baculatus* itself). I shall show that true spines with spinal canalsystem are not formed in *Tinoporus*, and that in microspheric forms they are often not developed at all. Other characteristics are known which can be pointed out as always being present in our genus: a raspberry-like megalospheric apparatus, a rotalide microspheric one, always followed by an irregular mass of chambers, suddenly passing into radiating rows of chambers. Moreover the places of the foramina are very characteristic. As in some megalospheric individuals columns of shellsubstance are almost absent, these columns are of no systematical value from a generic point of view. And, as I shall explain when describing the genus *Polytrema*, even the raspberry-like megalospheric apparatus is not always constant, only the absence of a canalsystem, the position of the chambers and of the foramina are characteristic.

Characteristics of the genus *Tinoporus* Montfort.

Test lenticular or globular, in megalospheric individuals often beginning with a raspberry-shaped megalospheric apparatus, in microspheric forms always rotaliform. The initial chambers are followed by an irregular clew of chambers, forming a globular mass. Suddenly this arrangement of the chambers is followed by radiating rows of chambers, and always a chamber of one row communicates with two chambers of the next by means of foramina. Spines often are formed by a characteristic growth of some of the chambers, but never is a true canalsystem found in these spines.

It was necessary for me to look for other species, referred to by other authors, which probably belonged to the genus *Tinoporus*, as I described above, and really I found some described as *Gypsina globulus* Reuss and *Gypsina vesicularis* Parker and Jones. SCHLUMBERGER [1]) also mentions the close relation between *Tinoporus* (= *Baculogypsina* Schlumb.) and these Gypsinae: "On trouvera sur la pl. III, fig. 4 une section médiane de *Gypsina globulus* Reuss, du calcaire grossier de Parnes et on reconnaîtra facilement l'étroite parenté de cette espèce avec *Baculogypsina Floresiana* Schlumb. Les loges primordiales sont semblables, les autres loges de *Gypsina* s'empilent, quoique avec moins de régularité, suivant les rayons de la sphère; mais il y a absence complète d'apoplupes et de piliers". As I will show, when dealing with *Tinoporus Floresianus* microspheric specimens show a great reduction of the spines. There may be some close relation between *Gypsina globulus* Reuss and those attached Gypsinae, called by CHAPMAN [2]) *G. howchini*. It is possible that in some Foraminifera the one generation lives free, whereas the other may be sessile.

In the Siboga-material there was only one small specimen of *Gypsina inhaerens*, and Mr. CUSHMAN was so kind as to send me some material of *Gypsina globulus* var. *pilaris* (Brady) from Jamaica. I also had the opportunity to study some material of *Gypsina inhaerens* from pliocene sands collected near Rovigno (Italy). I am sure now, that *G. globulus* Reuss, *G. pilaris* Brady and *G. inhaerens* Parker and Jones are all the same species, *G. globulus* and *G. pilaris* being the microspheric form, in all those cases, in which the microspheric form of *Tinoporus Floresianus* was not looked upon as *G. globulus*. These "Gypsinae" also commence with a clew of irregularly arranged cells, followed by radiating rows, and the foramina are placed in the same way as is the case in *Tinoporus*. So it is obvious, that these forms will be best classed under the name of *Tinoporus inhaerens* Parker and Jones, the name CARPENTER gave it in 1862.

Gypsina inhaerens (Schultze), *G. inhaerens* var. *plana* (Carter), *G. rubra* (d'Orb.), *G. vesicularis* var. *discus* and other varieties in which no radiating rows of chambers are met with, really belong to *Gypsina* s. s., which is more primitive, since the clew of irregularly arranged first chambers of *Tinoporus* is comparable with a whole *Gypsina*. There is some possibility that the orbitoidal genus *Orthophragmina* and especially its asteroidal varieties (*Asterodiscus*) resemble the forefathers of the genus *Tinoporus*. As I have already pointed out, the Orbitoids belong to the same family of the TINOPORIDAE and lack every trace of a canalsystem. GUPPY [3]) mentioned *Tinoporus asteriscus* from Trinidad Tertiary and says that the internal structure as shown by sections is similar to that of other species of *Tinoporus*, but makes one think of that of *Orbitoides* also. When dealing with the same Foraminifera, DOUVILLÉ [4]) added to it: "Ce sont des formes étoilées, généralement à cinq branches, qui sont bien certainement ce que GUPPY a nommé *Tinoporus asteriscus*. La coupe médiane montre qu'il n'y a aucune trace de l'enroulement spiral qui caractérise ce dernier genre: la forme et la disposition des logettes sont exactement celles des *Orthophragmina* et en particulier celles du genre *Asterodiscus* Schafthäutl. Cette espèce

1) SCHLUMBERGER, C., Note sur le genre *Tinoporus* (Mémoires de la Société Zoologique de France; vol. 19, p. 90, 1896).

2) CHAPMAN, F., A study of the Batesford Lime-stone (Proc. Roy. Soc. Victoria, N. S. vol. 22, 1909—1910, Pl. II, fig. 4 *a*, *b*; Pl. III, fig. 3—5).

3) GUPPY, L., Tertiary microzoa formation of Trinidad (Quart. Journ. Geol. Soc., London, vol. 48, p. 35, 1892).

4) DOUVILLÉ, H., Les Orbitoïdes de l'île de la Trinité. (Comptes Rendus des Séances de l'Acad. des Sciences, vol. 161, p. 90, 1915).

qui devra donc s'appeler *Asterodiscus asteriscus* (Guppy 1866).....". The only characteristic on which DOUVILLÉ bases the relation with *Orthophragmina* is the lack of a spiral embryonic set of chambers. But as we will show afterwards, real *Tinoporus*-species don't possess a spiral in megalospheric form, but a raspberry-type of embryon. The relation of *Tinoporus* with *Orthophragmina* in this way is much closer than DOUVILLÉ supposed. And even his denial of a relation between real *Tinoporus* with *Orthophragmina* here shows the close relation of these two genera.

1. *Tinoporus baculatus* (? De Montfort) Dervieux. Pl. IV, figs. 2, 6, 7, 8, 9, 10, 11; Pl. V, figs. 5, 6, 7, 10; Pl. VI, figs. 4, 8, 12, 13, 14, 15, 19.

Tinoporus baculatus ? Montfort, Conchyliologie systématique, vol. 1, 1808, p. 146; CARPENTER, Philos. Trans., 1860, p. 557, 564, pl. 18, figs. 2—10; pl. 21, figs. 5—11; CARPENTER, PARKER and JONES, Intr. Foram., 1862, p. 226, pl. 5, figs. 5—12; BÜTSCHLI, in Bronn, Klassen und Ordnungen des Thierreichs, 1880, p. 216, pl. 13, fig. 3; BRADY, Rep. Voy. Challenger, Zoology, vol. 9, 1884, p. 716, pl. 101, figs. 4—7; DERVIEUX, Atti R. Accad. Sci. Torino, vol. 29, 1893, p. 6, pl., figs. 19, 26, 34; SHERLOCK, Bull. Mus. Comp. Zool., Harvard college, vol. 38, 1903, p. 357, fig. 8; MILLETT, Journ. Roy. Micr. Soc., 1904, p. 598; CHAPMAN, Journ. Linn. Soc., Zool., vol. 30, 1910, p. 424; CHAPMAN, Journ. Linn. Soc., vol. 28, 1900—1903, p. 386, pl. 36, fig. 4; CUSHMAN, U. S. Nat. Mus., Bull. 100, vol. I, pt. 6, 1919.

Orbitolina sphaerulata Parker and Jones, Ann. Mag. Nat. Hist., ser. 3, vol. VI, p. 33; n° 8, 1860; ? MOEBIUS, 1878, Bau des Eozoon, p. 186, pl. 38.

? *Orbitoides stella* Gümbel, Abh. d. II. Classe d. K. Akad. d. Wiss., München, vol. X, pt. II, p. 716, Pl. II, figs. 117*a*, *b* and *c*, Pl. IV, figs. 8—10 and 19.

Stat. 7. 7° 55'.5 S., 114° 26' E., 15 m. and more. Near reef of Batjulmati (Java), some specimens.
Stat. 47. Bima-anchorage, 55 m.; abundant.
Stat. 53. Bay of Nangamessi, Sumba, up to 36 m.; abundant.

This species lives especially in the westerly part of the Timor-Sea and has probably spread westwards as far as the Sunda-Sea.

Characteristics of *Tinoporus baculatus*.

Forma A_1. No typical specimens of this form have been found in the material.

Forma B. Asteroid shells with a diameter of about 3 mm., with about five spines, covered with chalk tubercles and showing a lenticular shape. First chambers forming a spiral, followed by an irregularly heaped mass of chambers; afterwards the chambers grow in centrifugal rows. No true canalsystem. Columns of solid chalk between the chamberrows.

Forma A_2. Typical specimens of tetrad shape, with four blunt spines and surface covered with projecting ends of columns. First chambers typically raspberry-like. No trace of a true canalsystem. Rows of chambers forming with axis of spine an angle of 30°.

A great confusion characterizes all the older descriptions of this species. All specimens, having a rotaliform embryonic apparatus, followed by a more irregular mass of chambers, and provided with spines, have been gathered by CARPENTER (1860, 1862) under the name of

Tinoporus baculatus. Afterwards CUSHMAN [1]) showed, that some of these forms must be separated from the *baculatus*-group, having "the exterior with coarsely placed chambers, subglobular in shape and with coarsely perforated walls" and named them *Siderolites tetraedra* (Gümbel). The other specimens were gathered under the name of *Baculogypsina sphaerulatus* (Parker and Jones): "with numerous small finely punctate chambers, with four to eight, or even more sharp tapering spines". As we have already shown, the descriptions given by CARPENTER and BRADY refer to *Baculogypsina*; some figures however seem to have some connection with another species, undoubtedly belonging to the *baculatus*-group, viz. CARPENTER's [2]), being probably a representation of the megalospheric generation of our species. Since *Gypsina* and *Siderolites* have served as types to the older authors, when they described the Tinoporinae, the greatest weight has been laid on the irregularly massed chambers (RUMBLER [3]): "Tinoporinae: Schale aus unregelmässig zusammengehäuften Kammern bestehend, mit oder manchmal auch ohne einen mehr oder weniger deutlich spiral aufgewundenen Anfangsteil"). So it can be understood that the genus *Tinoporus* was said to possess these irregular heaps of chambers also. Younger shells of this species really have strangling heaped chambers surrounding the embryonic apparatus. But soon afterwards the growing of the chambers is not at all irregular. So it was necessary to give a new description of the genus *Tinoporus*.

It was DENYS DE MONTFORT who first figured a specimen which he named *Tinoporus baculatus* [4]) (DE MONTFORT's description has been cited by CUSHMAN [5])). W. K. PARKER and T. R. JONES critisised DE MONTFORT's figure in 1860 [6]) in the following way: "Modified from the figure of *Calcarina Spengleri*, var. a. F. d. M.; or, rather, this is apparently a curious hybrid picture, consisting of a three-spined *Orbitolina*, according to its surface-ornament and its vertical section, but outlined after a three-spined *Calcarina Spengleri* (such as fig. *e*, pl. 15, in FICHTEL and MOLL's "Test. microsc."). The indication of an aperture (the broken newest chamber in *Calcarina*) is also after FICHTEL and MOLL's figure. The sectional aspects in MONTFORT's woodcut appear to have been taken from the following sources: the vertical (Orbitoline) ones from nature, the horizontal (Calcarine) ones from FICHTEL and MOLL's fig. *k*, with the sectional feature of the spine (also Calcarine), added from some other source. Some stellate variety of *Orbitulina sphaerulata* may perhaps claim the name of *O. baculata* Montf.; but MONTFORT's indefiniteness may well lead us to drop the name altogether".

Having now a much better idea about the external and internal features of our species, it seems that DE MONTFORT was probably right in describing it as a "curious hybrid" thing; the microspheric form is very *Calcarine*-like, and *Siderolites* is without any doubt a developed *Calcarina*. Studying vertical sections of microspherical individuals we can affirm the great resemblance with *Orbitolina* in all cases, in which the section cuts two opposite spines. So I am not at all inclined to drop DE MONTFORT's name.

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1) CUSHMAN, J. A., The relationship of the genera *Calcarina*, *Tinoporus* and *Baculogypsina* (Bull. 100, U.S. Nat.Mus., vol. 1, pt. 6, 1919).

2) CARPENTER, W., Introduction to the study of the Foraminifera (Ray Society, 1862, fig. 9 on Pl. XV).

3) RHUMBLER, L., Foraminiferen von Laysan und den Chatham-Inseln (SPENGEL's Zoologische Jahrbücher, vol. XXIV, pt I, p. 72, 1906).

4) MONTFORT, DENYS DE, Conchyliologie systématique, vol. I, p. 146, 37me genre, 1808.

5) CUSHMAN, J. A., l. c., 1919, p. 364.

6) PARKER, W. K., JONES, T. R., BRADY, H. B. and KIRBY, J. W., On the nomenclature of the Foraminifera (Ann. and Mag. Nat. Hist., 1860, n° 3, ser. 3, vol. V).

CARPENTER (1860) gives a very beautiful description founded on several species, now distinguished as *Siderolites tetraedra* (Pl. XX, fig. 6; Pl. XVIII, figs. 7, 8, 9 and 10) and *Baculogypsina* (Pl. XVIII, figs. 2, 3, 4, 5 and 6). In his "Introduction" (1862) the description is once more based on *Baculogypsina*; only fig. 9 deals with *Tinoporus baculatus*, I suppose. The inner shape of the chambers was very well described, as *Baculogypsina* really resembles very much *Tinoporus* in this respect: "In the commencement of its growth, this organism seems closely to resemble *Planorbulina*, being formed by an assemblage of chambers arranged in one plane, spirally towards the centre, but irregularly clustered towards the circumference; each chamber communicating by single large septal orifices with the two contiguous chambers of the same row, whilst its walls are perforated with numerous large pseudopodian foramina. This first-formed plane, however, is afterwards covered-in above and below by numerous successive layers of similar cells, which are piled one upon another in very regular rows; the original spiral type of growth being altogether lost in these superposed layers".

"Now in *Tinoporus baculatus* we often find columns of solid shellsubstance interposed between the angular partitions of the piles of superposed shells, just as they are in *Orbitoides*, their summits being visible on the surface as projecting tubercles; these columns are perforated with pseudopodial canals, which are extensions of the pores in the walls of the chambers over which they lie".

The description of the canalsystem however leaves no doubt as to the real species, CARPENTER studied. BRADY (1884) doubtless had *Baculogypsina* in his mind, when describing *Tinoporus* ("The walls of the earlier chambers are considerably thickened, the additional deposit forming the commencement of the supplemental skeleton; ..... branching canals similar to that of *Calcarina*").

DERVIEUX (1893) first figured a true *Tinoporus baculatus* (figs. 19, 26, 34), typical megalospheric tetraedrical specimens. His friend DI ROVASENDA [1]) evidently studied *Siderolites tetraëdra*, DERVIEUX himself *Tinoporus baculatus*; so the latter is the first author, who sharply distinguished between these two genera: "Avendo esaminati gli esemplari, che vennero publicati come *Calcarina tetraëda* Gümbel dal mio amico Cav. Luigi DI ROVASENDA, dopo di avere studiato il genere *Tinoporus* molto minutamente per poter publicare la presente memoria, fui convinto che non si trattasse di *Calcarina* ma di tipici esemplari del *Tinoporus baculatus* Carpenter".

SHERLOCK gives no description; but fig. 8 in his report on Fiji gives a very fine specimen of *Baculogypsina*, as I will state further on (see *Baculogypsina*).

MILLETT (1904) gives no description, so one can not say, if he found true *Tinoporus baculatus* or not. The same may be said of CHAPMAN's account (1910).

It was CUSHMAN who studied the relations between the different species, gathered by CARPENTER under the name of *Tinoporus baculatus* (1919). He came to the conclusion, that no living species can be identified with DE MONTFORT's *Tinoporus*; probably it is a species of *Calcarina*: "Biconvex, hispid, centrally tuberculate, spines four or five, distinct: *Calcarina baculatus* (Montfort)?". As we shall see further on, the microspheric form of our species certainly satisfies these conditions; CUSHMAN never described the megalospheric form, which was first figured by DERVIEUX under this name.

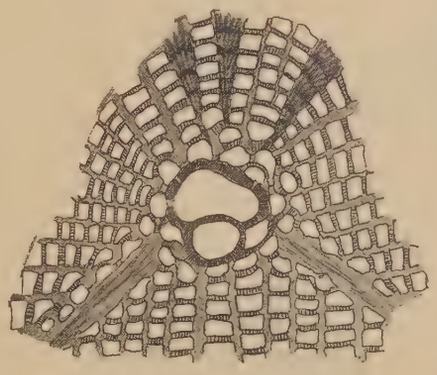
1) ROVASENDA, C. L. DI, Fossili di Gassino (Boll. Soc. Geol. Ital., vol. XI, p. 420, Roma, 1893).

There are some reasons to believe, that DE MONTFORT's figure deals with a microspheric individual of our species; in this case DE MONTFORT was the first who gave the name to it and he has priority over the others. But it remains to be seen, whether the microspheric or the megalospheric form must be looked upon as the type of the species. From a practical point of view, as microspheric forms are always rare, it will be wise to give the precedence to the megalospheric generation. Theoretically speaking we always see that the megalospheric forms have more typical features belonging to the species than microspheric ones, the latter being more primitive in their inner and outer shape. It is therefore, that we will give the priority to DERVIEUX.

Description of *Tinoporus baculatus* (Montfort) Dervieux emend.

Megalospheric generation.

Most individuals have a tetraëdrical shape, somewhat like the seeds of spinage (Spinacia oleracea). The distance between the tops of two adjacent spines amounts to 3 mm. The whole body (even the tops of the spines) is covered with bloating chamberwalls, and here and there the volcano-like summits of solid columns project. The pores in the chamberwalls are rather coarse, and the free tops of the solid columns of shellsubstance show little furrows directed from the pores of the next chamberwalls to the summit, as if the pseudopodia had worn out the slopes of these little mountains (Pl. V, fig. 3). The chambers on the surface of a fullgrown individual have a diameter of ± 100 μ. The centre of each shell is occupied by the megalospheric apparatus (textfig. 1). The megalosphere (diam. ± 120 μ) has a globular form, and is followed by a second chamber of the same aspect. The egg-shaped third chamber of the megalospheric apparatus has a much larger size. Its axis forms a cross with the two former chambers. The two corners between these chambers are filled up with other chambers, forming in this way a compound mass, surrounded by a solid, but not extraordinarily thickened wall of shellsubstance (see *T. Floresianus*, Pl. V, figs. 12 and 15). This embryonic apparatus is surrounded by an irregular mass of small chambers, three or four rows thick, followed by regular rows of chambers, radiating to the outside (Pl. IV, fig. 7, Pl. VI, fig. 13). It is obvious, that these rows often bifurcate, the breadth of these chambers growing slowly. The chambers communicate with each other by foramina, breaking through the radiating walls, while the tangential walls are perforated with numerous coarse pores. The place of the foramina is very characteristic for the Tinoporinae. The chambers of two neighbouring rows alternate and in each radiating wall of a chamber there are generally four foramina; two of them communicate with the lower, two with the higher placed chamber in the next row (Pl. VI, figs. 16, 17). No other canalsystem was found between the walls of the normal chambers, not even in the neighbourhood of the initial chambers. At four points of the inner clew of chambers the four spines project, stretching to the edges of the tetrad. The inner structure of these spines is of considerable value for the determination of the systematical place of *Tinoporus* (Pl. IV,



Textfigure 1. *Tin. baculatus.*
Transverse section through megalospheric centre of a shell.

fig. 7; Pl. V, fig. 17; Pl. VI, fig. 12). As there is no canalsystem between the initial chambers, these spines cannot be built up as in the Calcarinae: a true canalsystem in these spines is totally absent. And yet they have some substitute for it; the chambers which surround the shellsubstance of the spines have a similar structure as those which build up the inner clew of the shell; they have no pores directing to the spine itself, but their foramina reach up to the inner parts of it. These foramina anastomose with each other and are always bent towards the top of the spine; together they form a kind of canalsystem, which can be compared with that in the spines of *Siderolites*, considering that the real canals are absent and only the foramina of the surrounding chambers, which in *Siderolites* join these canals, have been left. The surrounding chambers of the spines are followed by regular rows of them, and these rows radiate from the spine, if one observes a transverse section through it. The rows are directed towards the top of the spine, and form an angle with it of about 60—65°. It is clear, that the rows of chambers must radiate like a fan in the middle of the shell having opposite directions in opposite spines. I have already mentioned that they bifurcate for this purpose, but this is not enough; in most individuals there are between the rows of chambers masses of solid shellsubstance, growing periodically as the shell itself does, and projecting on the surface like little volcanoes (Pl. V, figs. 3, 8, 9; Pl. VI, figs. 5, 9). In some individuals these columns are very big, and the diameter of the little mountains on the surface is much larger than that of the surrounding chamberlets. In other individuals however the pillars only fill up the corners between the chambers and don't strike the eye. I have been able to ascertain, that the individuals with big pillars have a smaller embryonic chamber than those with small pillars, and I suppose, that this is another case of true polymorphism: the individuals with small megalosphere have big pillars; as we shall see, the microspheric generation possesses large pillars.

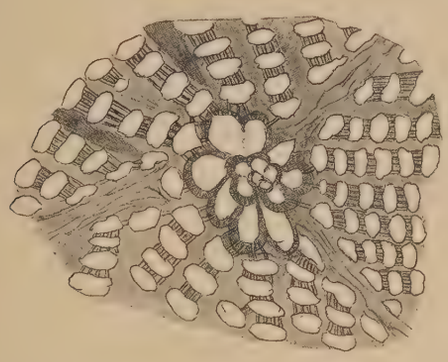
Microspheric generation (Pl. IV, figs. 6, 9; Pl. VI, fig. 4).

Among the individuals, gathered at Station 53, there were two which had the same structure of chamberlets, pillars and spines as the forms we have described just now, only the study of the initial chambers showed that here we had a microspheric generation. The external features however are very different from the typical characteristics of the tetraedric individuals of megalospheric *Tinoporus baculatus*, the shell having a compressed lenticular shape (and a diameter of about 4 mm.), with five or six radiating spines, just as in *Calcarina* and in *Baculogypsina*. As these shells are in all other respects similar to *Tinoporus baculatus*, I did not hesitate to class them with this species. The shell is covered with normal chamberwalls, with here and there the summits of very big columns. We are able to distinguish a dorsal and a ventral side of the shell, the dorsal side being more convex than the ventral one (textfig. 2). The spines are big (textfig. 4), hispid and blunt, and often bifurcate, one top dorsally of the other.

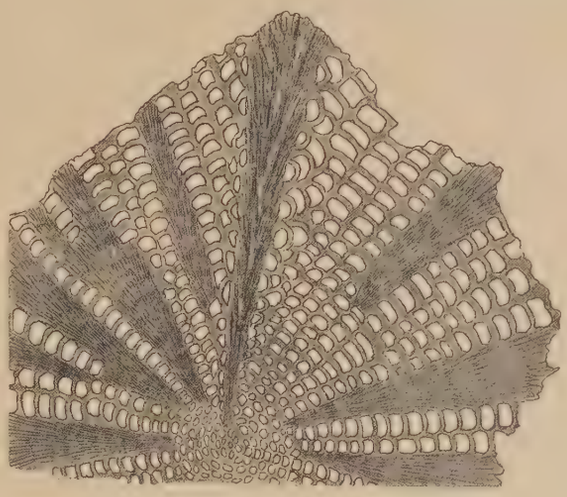
Textfigure 2. *Tin. baculatus.* Vertical section, showing dorsal and ventral side of the shell.

The microsphere (diameter ± 24 μ) is followed by a typical rotalide set of chambers

(textfig. 3), with thickened walls, especially on the dorsal side (textfig. 2). I doubt whether a reduced umbilical canalsystem is present, but I had not sufficient material to form an exact opinion. In the centre of the shell lies the microsphere; the difference between the dorsal and the ventral side is caused by the fact, that the spines do not grow in a horizontal plane, but are turned down. Young microspheric specimens have large rigid spines. In megalospheric individuals the protoplasm could be studied. An irregular mass of chromatin substance is found, especially in the biggest chamber, and in most cases the initial chambers are filled up with big vacuoles whilst the protoplasm and the nucleus are reduced (Pl. VI, figs. 13, 14). The granular protoplasm in the other chambers is filled up with chromatin substance in fullgrown animals and often this



Textfigure 3. *Tinoporus baculatus*. Horizontal section, highly magnified, showing first spiral of chambers of microspheric specimen.



Textfigure 4. *Tinoporus baculatus*. Microspheric. Transverse section.

chromidium is coagulated into definite masses (Pl. VI, fig. 18). But these phenomena can better be described in *Tinoporus Floresianus*.

Some individuals show irregular heaps of swollen chambers on the surface; sections pointed out, that these are gigantic chambers, furnished with a thick organic wall; the protoplasm here is filled up with nuclear material, and often one distinct nucleus was found in one of the heaps of chambers (Pl. V, fig. 7, Pl. VI, fig. 12). Probably one may compare these gigantic chambers with the excrescences in *Calcarina Spengleri* we shall mention afterwards. As I have shown already, the microspheric generation has more than one primitive characteristic, peculiar to *Planorbulina* (rotalide first chambers, lenticular shape), which is evidently a more primitive form, having a more rotalide shape. In *Tinoporus Floresianus* we see a species which even in the microspheric generation has lost more than one primitive characteristic. So we can assert without any doubt, that *Tinoporus baculatus* is more primitive.

2. *Tinoporus Floresianus* (Schlumberger). Pl. IV, figs. 1, 3, 4, 5; Pl. V, figs. 1, 2, 3, 4, 9, 11, 12, 13; Pl. VI, figs. 1, 2, 3, 5, 6, 7, 9, 10, 11, 16, 17, 18, 20, 21.

Baculogypsina Floresiana Schlumberger. Mém. Soc. Zool. France, vol. IX, 1896, p. 88, Pl. III, figs. 1, 2, 3; Pl. IV, fig. 7.

Stat. 58. Anchorage off Seba, Savu, up to 27 m.; abundant.
Stat. 93. Pulu Sanguisiapo, Tawi-Tawi-islands, Sulu-Archipelago, 12 m.; one specimen.

Stat. 299. 10° 52′.4 S., 123° 1′.1 E. South-coast of Rotti, 34 m.; some specimens.
Stat. 303. Haingsisi, Samau-island, up to 36 m.; ± 30 individuals.
Stat. 306 and 307. Shore-exploration, Sikka, Flores, reef, also on sea-weed; very abundant.
? Stat. 321. 6° 5′.5 S., 113° 30′ E. 82 m.; one specimen.

The species is a typical inhabitant of the easterly part of the Timor-sea.

Short characteristics of the species:

Forma A_1. Globular shells with large tubercles (ends of columns) on the surface, separated by chamberwalls. Spines very rare. Diameter up to $1^1/_2$ mm.

Forma B. Larger globular shells, up to $2^1/_2$ mm., with irregularly arranged columns and spines seldom developed. First set of chambers a small spiral.

Forma A_2. Tetrangular shells with rounded periphery and covered on the surface with projecting ends of columns. Four spines, beginning in the inner part of the shell, which is formed by a raspberry, followed by an irregular clew of small chambers. Rows of chambers forming an angle of about 60°. No canalsystem exists.

Megalospheric generations.

Ordinarily there are two forms of megalospheric specimens; one of them has a globular shape, the columns are big and project on the surface as small tubercles, which can be seen with the naked eye, the spines are reduced and do not project on the surface (Pl. IV, fig. 4; Pl. VI, fig. 2); the other, on the contrary, has very minute columns, projecting scarcely on the surface, but well-developed spines, normally at the four angles of a tetrad (Pl. IV, fig. 3, Pl. VI, fig. 3). Yet the latter form does not resemble a seed of spinage, because the sides of the tetrad are convex, and the whole shape of the test is nearly globular. In some individuals the columns are very small, even totally absent. As sometimes the shells have been eroded by the breakers, the chamberwalls on the surface have disappeared and then the surface is covered with a typical network of chamberwalls, with here and there the still projecting columns of clean shellsubstance, which look very much like those of *Tinoporus baculatus*.

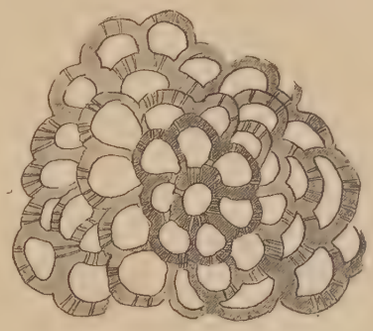
The megalospheric apparatus is very similar to that of *T. baculatus*, only the third chamber looks more like a kidney. These embryonic chambers are also followed by small chambers, arranged in a clew, and then followed by long rows of chambers, radiating to the periphery. There is a marked difference between the arrangement of the chambers of *T. baculatus* and of those of *T. Floresianus*: in the latter the rows of chambers form an angle of 60° with the axis of the spine (Pl. V, fig. 1), in the former, as already mentioned, one of 30°. It is this difference which leads to the difference in the shape of the whole shell, as the swollen form is a consequence of this particularity. In some specimens, filled up with canadabalsam and afterwards decalcified, I could observe the canalsystem of the spines. The chambers which surround the spines have the same shape as those which surround the embryonic apparatus; the foramina of these chambers, as I have said already when describing the spines of *T. baculatus*, are prolonged to the periphery, and often end in a bundle of finer canals, which open on the

surface (Pl. V, fig. 17). As afterwards this surface is covered with a layer of chambers, due to the growth of the animal, the canals open into these chambers (Pl. V, fig. 18). The large canals in the spines are surrounded by clear shellsubstance, formed by the protoplasm which streams through them, and on a section each part of the spine, surrounding a canal, forms a wedge-shaped sector of the circular section (Pl. V, fig. 13).

The megalosphere has a diameter up to 140 μ. The individuals with spines have a diameter of about 1.5 to 2 mm. Forms provided with spines are in most cases larger, measuring generally 2.5 mm.; with respect to their size, the projecting columns and the slight development of the spines, they approximate to the microspheric forms.

Microspheric generation (Pl. IV, figs. 1, 5; Pl. V, fig. 1).

Fullgrown specimens attain a height of diameter 3.5 mm. and have a globular shape. In younger individuals the spines are very well visible, in older forms they are overgrown with shellsubstance.



Textfigure 5. *Tin. Floresianus.* Centre of microspheric individual.

The columns are projecting like very irregular peaks and even take the shape of spines (Pl. IV, fig. 1); on the chamberwalls are often sharp spicules of shellsubstance, projecting into the air. In this way the microspheric individuals have a very rugged external structure. Most of the spines lie in a horizontal plane, the same in which the first coils of the rotalide embryonic apparatus are arranged; but some of these spines project in other directions. The initial chambers of the shell have no thickened walls as in *Tinoporus baculatus*, only the primary walls have got a more yellowish colour (textfig. 5).

Yet there are more differences between the micro- and the megalospheric forms of this species. It is a wellknown fact that the two generations differ not only in the shape of the embryonic chambers, but also with regard to the structure of the later formed chambers. In one case there are differences between the two forms with regard to the following measures (the numbers give only an average relation):

	Microspheric forms	Megalospheric forms
Thickness of radial chamberwalls	7·3	5·7
Thickness of tangential chamberwalls	6.2	3.0
Breadth of the chambers at surface.	19·3	19·3
Number of chambers in a row of fixed length.	16.0	9·7

There is a remarkable difference between *Tin. Floresianus* and *T. baculatus*, viz. in the number of chambers in the irregular clew of chambers, following the initial ones. There are in *T. baculatus* three or four rows, in *T. Floresianus*, however, even to twelve rows of these chamberlets.

Protoplasm.

Young megalospheric specimens show within the second chamber a kidney-like or globular

nucleus, with numerous chromatin granules in a network of threads. At a later stage the chromatin of the nucleus begins to agglomerate into greater heaps and finally the chromatin collects at the periphery of the nucleus. Probably the chromatin leaves the nucleus and spreads among the protoplasm. In fullgrown individuals one finds a nucleus without membrane, amoeboid shaped, eosinophile, with elongated nucleoli, as if the nucleus had been in motion. Often the branches of the irregularly shaped nucleus protrude into the third chamber. Afterwards the material of the nucleus is absorbed by the protoplasm and a great vacuole, surrounded by irregularly massed chromatin substance, takes the place of the former nucleus. The whole protoplasmic body is filled up with eosinophile parts of nucleolar substance, surrounded by scales of protoplasm, and often has a dumb-bell-like shape, as these little nuclei stream through the narrow foramina of the chambers. In some cases there were only masses of chromatin substance in the protoplasm, without any structural characteristics. The outer layers of protoplasm are filled up with all kinds of food.

In microspheric individuals only remainders of the nucleus have been found, but in nearly every peripherical chamber one will find a nucleus and these nuclei are connected with those of neighbouring chambers by means of threads of protoplasm or of chromatin masses. The whole gives an idea of a chromidium.

This species has already been described by SCHLUMBERGER (1896) under the name of *Baculogypsina Floresiana*. Though SCHLUMBERGER in his introduction gives notes on the relation between *Tinoporus* and *Baculogypsina*, his insufficient investigations did not give him a clear idea of the structure of the shell. He also describes the four spines ("apophyses saillantes"), but does not remark the essential difference between these "apophyses" and the canaliculated spines of *Baculogypsina*. The globigerinous shape of the embryonic chambers in megalospheric specimens is also mentioned by SCHLUMBERGER, but though he says, that *Baculogypsina sphaerulata* "au lieu d'un amas de trois ou quatre loges primordiales . . . . . a ses loges initiales disposées dans une spire régulière", he does not observe this important difference. SCHLUMBERGER does not make mention of a canalsystem in the spines but "les quatre apophyses . . . . . sont traversées par de larges tubulures sinueuses qui mettent en communication la partie centrale avec l'extérieur". There is a mistake in SCHLUMBERGER's observations, when he says that "les piliers . . . . . sont formés de couches superposées de calcaire compact traversé par de nombreux canaux en éventail". The fine chalk-needles forming the columns must have suggested this idea to SCHLUMBERGER.

IV. Genus **Sporadotrema** Hickson.

To this genus I bring four species, viz. *S. macroporum* (Lamarck) from the chalk of Maestricht, *S. rubrum* (d'Orbigny), *S. cylindricum* Hickson, *S. mesentericum* (Carter).

As *S. macroporum* is the most ancient species, this species probably shows the most primitive characteristics. It is a free-living species, the initial chambers in both micro- and megalospheric forms show the characteristics of *Planorbulina*. Afterwards two layers of chambers are formed in a cyclical or spiral arrangement, with communication between the layers by means of stoloniferous foramina, forming hollows between the layers.

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The chambers obtain a gigantic size [1]).

From this species has sprung *Sp. cylindricum*. This species shows all the characteristics of the fossil form except that the sessile life has added some peculiarities. The microspheric form shows the typical arrangement of initial chambers, the megalospheric shows the raspberry.

Sporadotrema mesentericum shows a close relation with *Sp. cylindricum*; the arrangement of the latter chambers is somewhat more irregular, the microspheric initial chambers show the shape of the megalospheric set of chambers of *Sp. cylindricum*.

What to think of the systematical place of *Sp. rubrum*, I do not know exactly. Either it is a species, even older and more primitive than *Sp. errantium*, showing no raspberry in the megalospheric form, or the raspberry has disappeared, owing to the sessile life of the animal. There is some possibility, that the organism, described by REUSS [2]) as *Thalamopora cribrosa* Goldf. is nothing but some species of *Sporadotrema*.

1. *Sporadotrema rubrum* (d'Orbigny). Pl. VII; Pl. VIII, fig. 8.

Planorbulina rubra d'Orbigny, Tableau méthodique, etc., 1826, p. 280, n^0 4; FORNASINI, Memorie d. Real. Accad. della Science, Bologna, 1908, p. 44, pl. II, fig. 3.
Gypsina rubra (d'Orbigny) Heron-Allen and Earland, Trans. Zool. Soc., London, vol. XX, Pt. II, 1915, p. 725—726, Pl. LIII, figs. 35—37.

Stat. 19. 8° 44'.5 S., 116° 2'.5 E. 18—27 m.

It was found with incrusted shells, sponges or chalk rocks. Very beautiful specimens have been collected by Dr. H. BOSCHMA in the neighbourhood of the Island of Edam, near Batavia, on a piece of coral.

Only forma A_1 has been met with.

Short diagnosis of the species:

Attached, forming a single layer of large chambers of a pinkish colour. Surface generally ornamented with spines of secondary chalk. Pores very large and sometimes melting together. First chambers forming a regular spiral. Foramina very large, mostly four in each chamber.

This very remarkable species shows in most characteristics the shape of *Planorbulina* (Pl. VII, fig. 2; Pl. VIII, fig. 8); the place of the foramina between the chambers is just the same; the coarsely punctated chamberwalls are very much alike. The megalospheric apparatus is of the typical rotalide kind (Pl. VII, fig. 3), which also occurs in some species of *Planorbulina*, as is the case in *Planorbulina larvata* (*Linderina*). There are, however, some differences too: the chambers are of an unusual size, which is common to *Sporadotrema*; the secondary chalk-substance is also met with on the walls of the lastformed chamber (Pl. VII, figs. 1 and 4), as is the case in *Sporadotrema*; the colour is pinkish (Pl. VIII, fig. 8), which never occurs in Planorbulinae; the growth of the chambers is not cyclical, but irregular or spiral; radial

1) HOFKER, J., Die Foraminiferen aus dem Senon Limburgens, IV, *Sporadotrema errantium* (Natuurh. Maandbl., Maestricht, vol. 15, n^0 6, 1926, p. 62—65).

2) REUSS, A. E., Die Bryozoen und Foraminiferen des unteren Quaders (Palaeontographica, vol. 20, pt. 1, 1871—1875).

rows are never met with. All these characteristics are doubtless those of some organism, allied to *Sporadotrema*. That is why I mention it here and under this generic name.

The individuals are all of megalospheric form; the megalosphere of about 70 μ. is followed by a spiral of about 9 chambers, like those of a *Truncatulina*, followed again by the more cyclically arranged chambers. At the periphery the outer two foramina of each chamber sometimes form lips. The spiral arrangement of the initial chambers is of slight importance from a systematical point of view, the arrangement of megalospheric initial chambers being very inconstant; this primitive shape is obviously due to the manner of life. It is, however, possible that the spiral arrangement is due to the low place of the organism.

2. *Sporadotrema cylindricum* (Carter). Pl. VIII, figs. 3, 5, 6; Pl. IX, figs. 1, 2, 3, 4, 6; Pl. X, figs. 1—10, 12, 13.

Polytrema cylindricum Carter, Ann. Mag. Nat. Hist., ser. 5, vol. V, p. 441, Pl. XVIII, fig. 1, 1880; BRADY, Challenger Reports (Zool.), vol. IX, p. 720, 1884.
Sporadotrema cylindricum Hickson, Trans. Linn. Soc., London, p. 447, Pl. XXX, figs. 3—7, Pl. XXXI, figs. 10—17, Pl. XXXII, figs. 21, 22, 24, 29, 32, 33, 1911; HERON-ALLEN and EARLAND, Trans. Zool. Soc., London, vol. XX, pt. II, p. 729, 1915.

Stat. 80. 2° 25′ S., 117° 43′ E. From 50—40 m.
Stat. 81. Pulu Sebangkatan, Borneo-bank. 34 m.
Stat. 96. South-east side of Pearl-bank. Sulu-Archipelago. 15 m.
Stat. 99. 6° 7′.5 N., 120° 26′ E. 16—23 m.
Stat. 144. Anchorage north of Salomakiëe (Damar) island.
Stat. 204. 4° 20′ S., 122° 58′ E. 75—94 m.
Stat. 303. Haingsisi, Samau-island, up to 36 m.

Description:

Yellow or orange trees with big stem and branches with obtuse ends. Pores melting together to form large openings scattered on the surface. A number of chambers in the tree are arranged spirally round a network of large canals without pores.

Forma A_1. See "facies Amirantiae", II.
Forma B. See under III. A planorbuline first set of chambers.
Forma A_2. See "facies Providentiae", I.

Three forms can easily be distinguished in the Siboga-material, which is, however, far from being sufficient, so that conclusions with respect to the biological relations between these forms have only provisional value.

I will first mention these forms together with the stations, where they were found.

I. There is the typical *Sporadotrema cylindricum facies Providentiae*, as HICKSON called it, and which I had the pleasure to compare with the original specimens, HICKSON described, from Providence. It is not a common form (Stat. 204, Pl. VIII, fig. 5). On a very thick-walled trunk are placed relatively short branches, at the tops of which only the outlines of the chambers are visible. All of them have an orange colour.

II. *Facies Amirantiae*, a commoner creature in the material with long branches, which

are not much thickened. They are never red, as HICKSON says, and I am sure there must be some mistake in this respect, as I will show afterwards (see *S. mesentericum*) (Stat. 80, 96, 99, 204, 303; Pl. VIII, fig. 3).

III. I am not sure I found the third facies of HICKSON's, viz. *Saya de Malhensis*, and I believe that this facies is only a geographical one. Yet there are other individuals, very much like small specimens of *f. Providentiae*, with short branches but not such a thick trunk, on which here and there the outlines of the chambers are visible. The colour of these individuals is more orange-red than those of the preceding facies, which are more yellowish. I believe that HICKSON classes these forms with the *facies Providentiae*, though his fig. 7, pl. 30 deals with an individual which probably belongs to this form (Stat. 81, 96, 144, 303; Pl. VIII, fig. 6).

The chambers of *Sporadotrema* are very characteristic. They are very large, ± 450 μ diameter, and are only situated at the periphery of the shell. The central parts of the individual are occupied by a network of irregularly shaped tubes, formed by the foramina of the chambers (Pl. IX, fig. 6). These chambers have only pores towards the periphery and communicate with each other only by means of the foramina; they are arranged in spirals around the trunk and branches of the tree. This peculiar arrangement of the chambers, the coarse perforations, the building of stoloniferous foramina within the trunks, are characteristics which are also met with in the particular "*Orbitolites* (= *Omphalocyclus*) *macropora*" from the chalk of Maestricht. In older specimens the basal chambers of the shell show a peculiar thickening of the organic layer of the shellwalls, and the pores are also filled up with this organic, brown coloured material, so that they do not open without any more (Pl. X, fig. 9). As the embryonic characteristics of *Sporadotrema cylindricum* also show identical features with this fossil, the relation between these two species must be very close.

The central tubes in *Sporadotrema* are often very big and open at the tops of the branches, together with the large foramina of the chambers, as HICKSON has described already.

In most cases the embryonic apparatus lies under the surface of the calcareous algae which the individual is attached to. If you break the coral-shaped shell from the stone, on which it is growing, you will find a little hole in this stone, and following this hole, which is nothing else but a tube belonging to the animal, you will reach the embryonic apparatus, in some cases even one mm. or more beneath the surface (Pl. IX, fig. 2). I do not know whether the young *Sporadotrema cylindricum* sinks in beneath the surface of the calcareous algae by means of an acid substance or something like it, or whether the algae overgrow the young *Sporadotrema* after it has settled down on their surface. In this connection I wish to observe that HERON-ALLEN described *Cymbalopora tabellaeforma*, sinking into cavities in the shells of molluscs [1]).

I first will mention a section through a specimen of *Sporadotrema cylindricum fac. Amirantiae* kindly lent to me by Mr. HICKSON, and figured in his paper, Pl. 32, fig. 29 (Pl. X, figs. 1, 2 and 3). On examining my own preparations I found that the chambers, indicated in this figure by the letters *ic*, are not the initial chambers, though I have to admit that at first I also thought that these large chambers, occurring at the base of the stem, were initial ones. The study of the preparation of HICKSON taught me that there were two sets of initial chambers

1) HERON-ALLEN, E., Contributions to the study of the Bionomics and reproductive Processes of the Foraminifera (Phil. Trans. Royal Soc., London, Ser. B, Vol. 206, p. 258—261, 1915).

at the very base of the specimen, and later on I often examined this plurivalence of the embryonic apparatus.

In the Siboga-material the first chamber was found to be a megalosphere (Pl. IX, figs. 2 and 3). A megalosphere also occurs in real *Sp. cyl. fac. Providentiae*, but it appeared that in these forms the megalosphere was larger than in *fac. Amirantiae*. The initial chambers form a kind of short spiral, which often resembles a clew of chambers, the "raspberry-type", which was also met with in *Sp. macroporum*. These chambers are followed by irregular tubes, one of them piercing through the calcareous algae to the surface, where the coral-shaped shell begins. Some of these irregular chambers, which have but very few pores, possess a very characteristic shape; they show branch-like outgrowths and often these branches communicate again with each other; thus round openings are formed, as is also seen in microspheric individuals of *Sporadotrema mesentericum* (Pl. X, figs. 12 and 13). It is further remarkable that the lower chambers of the stem of *Sporadotrema* show outgrowths towards the base of the little tree, as if to give it some support (Pl. IX, fig. 3). Similar outgrowths are also seen in the organism called *Rammulina Herdmanni* by DAKIN [1]).

The embryonic apparatus of the third form of *Sporadotrema cylindricum* appeared to be microspheric (Pl. IX, fig. 1). This is a most remarkable initial set of chambers. The first chambers are arranged spirally, but soon afterwards they are arranged more or less cyclically and give rise to a plane disc, very similar to a *Planorbulina*. The chambers grow larger and larger and suddenly the large chambers and stoloniferous foramina of the fullgrown tree appear. This initial set of chambers is of most important systematic value, as it shows the same characteristics as the disc of the fossil "*Spor. macroporum*" and moreover the alliance with the genus *Planorbulina*. There is another important reason to believe that *Sporadotrema* is allied to *Planorbulina*. This reason is: the shape of the organism, described by some authors under the name of *Gypsina rubra* d'Orbigny, mentioned above. I cannot find any argument why HERON-ALLEN and EARLAND (Kerimba-Archip., p. 725) gave to this organism the name of *Gypsina rubra*, as it shows no *Gypsina*-characteristics. Real *Gypsina*-species always have chambers which communicate with each other by means of pores as well as of foramina; in *Planorbulina* and in *Sporadotrema* a communication by means of pores is very rare; in *Orbitoides* the initial disc only shows communication by means of foramina, etc.; and this is also the case with "*Gypsina*" *rubra*. I have never met with a specimen of *G. rubra* having more than one layer of chambers; on the other hand this species shows a remarkable secondary growth of the chamber-walls, which is very similar to what is found in *Sporadotrema*, but which was never met with in other Gypsinae. This very remarkable point has already been found by HERON-ALLEN and EARLAND; between the pores the walls are thickened, forming spines of shellsubstance. Very often these spines grow together and then more than one pore opens into the cavity formed by the secondary growth. This is on all fours with the remarkable melting together of the pores of *Sporadotrema*. So I believe that this "*Gypsina*" *rubra* really belongs to the group of *Sporadotrema*. It is a *Sporadotrema* lacking the stoloniferous outgrowths, which are not necessary, as the individual forms only one layer. Enchalked chambers of *G. rubra* are identical with those of *Sporadotrema*. So I intend to call this species *Sporadotrema rubrum*.

1) DAKIN, W. J., Report on the Foraminifera (Report Pearl Oyster Fisheries of the Gulf of Manaar Pt. V, p. 226—228, 1906).

3. *Sporadotrema mesentericum* (Carter). Pl. VIII, figs. 1, 2, 4, 7; Pl. X, figs. 11, 12, 13.

Polytrema mesentericum Carter, Report on Specimens dredged up from the Gulf of Manaar, Ann. Nat. Hist., Ser. 5, Vol. 1880, p. 437.
Sporadotrema mesentericum (Carter) Hickson. On Polytrema and some allied genera. Trans. Linn. Soc. London, Zoology, Vol. XIV, Pt. 3, 1911, p. 452 and 453, Pl. 30, fig. 5, Pl. 31, figs. 11 and 12.

Stat. 41. 7° 25′ S., 117° 50′.5 E. 96 m.
Stat. 60. Haingsisi, Samau-island, Timor. Reef, 23 m.
Stat. 96. South-east side of Pearl-bank, Sulu-Arch. 15 m.

General characteristics:

Red individuals forming trees, often with fan-shaped branches, in some cases more like crusty mosses. Inner structure that of *Sp. cylindricum.*

Forma A_1. A tree with high-shot-up branches.

Forma B. First chambers spirally arranged, later chambers of the base of the trunk irregularly shaped.

Forma A_2. Short trees with flattened branches. Embryonic apparatus a raspberry.

There are also three forms, I think, belonging to this species, closely allied to *S. cylindricum.* At first I thought they belonged to this species, but afterwards having found even a microspheric specimen of a dark red colour, it is very probable that other forms of the same colour, called *S. cylindricum* by earlier authors, really belong to *S. mesentericum.*

Description of the three forms:

The first has already been figured by Hickson (Pl. 30, fig. 4, Pl. 31, fig. 13), and described as a red variety of the *facies Saya de Malhensis.* I have nothing to add to Hickson's description, except that these individuals are megalospheric (Pl. VIII. fig. 7). A second form has also been described by Hickson (Pl. 30, fig. 6), called by this author a red variety of the *fac. Amirantiae.* The typical dark red colour and the short somewhat fan-shaped branches are very characteristic (Pl. VIII, figs. 1 and 2). Only a single specimen of this form could be examined, and it is for that reason, that the results are somewhat uncertain, though the research was made very carefully. The arrangement of the chambers is quite identical with that of *Sp. cylindricum*, and I believe this individual was also megalospheric.

Afterwards I found in the material a little dark-red coloured *Foraminiferum*, much like a young little *Sporadotrema mesentericum*, but yet provided with the typical spirals of chambers forming the branches. Only the base and a few irregular chambers in the middle of it forming a little hill, were visible (Pl. VIII, fig. 4). After I had decalcified it, I found it to be a microspheric individual with chambers surrounding the initial chambers, which were identical with those at the base of megalospheric *Sporadotrema cylindricum.* The large chambers were nothing but the first chambers forming the irregular tubes in the centre of the branches. So it is possible that this individual was a true microspheric form of *Sp. mesentericum.* This microspheric form shows, as we have already mentioned in our introduction to the genus, some remarkable characteristics of systematic value (Pl. X, figs. 12 and 13).

V. Genus **Polytrema** Risso.

This genus must be looked upon as an aberrant form belonging to the *Tinoporus*-group. Nothing is known about its real alliance with other Foraminifera. Only the facts that the chambers possess coarse pores, that no canalsystem is met with, that the embryonic apparatus of megalospheric form often shows the raspberry-type and that microspheric specimens begin with a rotalide test, show its relation to *Planorbulina*. The formation of tubes is another fact, which must be mentioned.

Most typical characteristics are the incrusting growth — best developed in the rather unknown *Polytrema papyracea* Chapman — and the shape of the later chambers with their foramina grown into pillars.

Some dubious forms have been described under the name of *Polytrema*. SCHUBERT [1]) named a Foraminiferum *Pol. planum* Carter; the figure, though very bad, shows only rows of cells as they occur in *Gypsina*. There are in this figure no traces of the *Polytrema*-structure, though SCHUBERT affirms, that "die Struktur auffallend mit jener von *P. miniaceum* übereinstimmt". It seems to me, that CHAPMAN [2]), too, was wrong, when saying that *Gypsina melobesioides* Carter would be identical with *Polytrema miniaceum* var. *involva*, and that *P. involva* would be the same as *P. planum* Carter. I believe that it is very necessary to study again all these so-called species of *Polytrema*. I am sure that many of them are nothing else but Gypsinae, e. g. trimorphic varieties of *G. plana* Carter.

1. *Polytrema album* (Carter). Pl. XI; Pl. XXX, figs. 1, 8, 9.

Polytrema miniaceum, var. *album* Carter, 1877, Ann. Mag. Nat. Hist., ser. 4, vol. XIX, p. 213, Pl. XIII, figs. 14, 15.
Polytrema miniaceum, var. *alba* Brady, 1884, Challenger Reports, Zoology, vol. IX, p. 721, Pl. CI, figs. 2, 3; CHAPMAN, 1900, Journ. Linn. Soc., London (Zool.), vol. XXVIII (1902), p. 201; CHAPMAN, 1901, Proc. Linn. Soc., London (Zool.), vol. XXVIII (1902), p. 393, n° 11; HERON-ALLEN and EARLAND, 1915, Trans. Zool. Soc., London, vol. XX, pt. II, p. 728.

This species was recorded from only two stations: 305 (Solor-strait, 113 m.) and 306 (8° 27′ S., 122° 54′.5 E., 247 m.), Sikka, Flores.

General characteristics:

Test attached, white or yellowish, forming small irregular crusts, as *Gypsina vesicularis*, but provided with "mouths", openings of a system of tubes in the centre of the shell. Surface pitted regularly by openings of the "pillar-pores", finely perforated in other places. Layers of chambers horizontal, chambers relatively small and regular. First chambers of forma A_1 a short, somewhat irregular spiral of about 4 chambers.

The specimens were attached on leaves of algae (Pl. XI, fig. 1), and only one kind of

1) SCHUBERT, R., Beitrag zur fossilen Foram. fauna von Celebes (Jahrb. der K. K. geol. Reichsanstalt in Wien, vol. 63, 1913, p. 146, Pl. VIII, fig. 1).
2) CHAPMAN, F., On some fossils of Wenlock Age from Mülde, near Klinteberg, Gotland (Ann. Mag. Nat. Hist., ser. 7, vol. 7, 1901)

megalospheric form was met with, viz. the form with a small first chamber and somewhat spirally arranged initial set (Pl. XI, fig. 4). It is wrong to look upon this species as a variety of *Polytrema miniaceum*; there are too many differences between these two forms. There are, however, even in the Siboga-material, several specimens of *P. miniaceum* with a very light colour, so that one might think one had to do with *P. album*. In these cases, however, the inner structure shows that the specimen in question belongs to *P. miniaceum*. The specimens of *P. album* show a white or somewhat yellow colour. They form irregular bosses on the algae with some protuberances on it, the mouths of the shell. These protuberances are somewhat shaped like a crater, but never reach the height of those of *P. miniaceum*; no more are branches ever formed. While in *P. miniaceum* the basal part of the shell at the periphery is very much flattened, the peripherical parts of the base of *P. album* are rounded. A transverse section (Pl. XI, fig. 2) shows that the layers of chambers are lower than is the case in *P. miniaceum* and they are shaped more horizontally. The pillars are very abundant and subsequently the chambers are shaped more irregularly, when seen from above (Pl. XI, fig. 5). These chambers are not so highly developed as in *P. miniaceum*, they are much smaller and not so strongly ramified. In the middle of the shell arise some tubes, just as in *P. miniaceum*; they reach the surface at the "mouths" of the shell. At their openings they are often filled up with sponge-spicules. The organisation of the organism is very similar to that of *Polytrema minutum* Chapman from the Tertiary of Victoria and from the Chalk of Maestricht. The only difference between these two species may be the higher development of the base and consequently the building of more than one mouth on the top of the shell. With respect to this observation I must add, however, that most specimens with multiple mouths were found to possess more than one embryonic apparatus. It is most probable that systematically *P. album* stands between *Polytrema minutum* and *P. miniaceum*.

2. *Polytrema miniaceum* (Pallas). Pl. XII; Pl. XIII, figs. 1—7; Pl. XIV, figs. 1—11.

Millepora miniacea Pallas, Elenchus Zoophytum (the Hague, 1766), p. 251; LINNÉ, 1788, ed. Gmelin, Systema Naturae, p. 3, 784, n° 6; DEFRANCE, Dict. Sci. Nat., vol. XXXI, p. 82, 1824; BLAINVILLE, Manuel d'Actinologie, 1834, p. 410.

Polytrema miniacea Carpenter, Parker and Jones, Introd. Study Foraminifera, 1862, pp. 228, 235, pl. XIII, figs. 18—20.

Polytrema miniaceum Carter, Ann. Mag. Nat. Hist., 1870, Ser. 4, vol. V, pp. 389—392; Ann. Mag. Nat. Hist., 1879, Ser. 5, vol. III, p. 411; MÖBIUS, Foram. von Mauritius, 1880, p. 85, pl. VII; BRADY, Challenger Reports, vol. IX, Foraminifera, 1884, p. 721, pl. C, figs. 5—9, pl. CI, fig. 1; SCHLUMBERGER, Mém. Soc. Zool. France, 1892, vol. V, p. 196, fig. 5; CHAPMAN, Proc. Linn. Soc. London (Zoology), 1901, vol. XXVIII (1902), p. 16, pl. IV, fig. 7; MERKEL, Zeitschr. f. wiss. Zool., 1900, vol. LXVII, pp. 291—322, pls. XVI, XVII; SIDEBOTTOM, Mem. Proc. Manchester Lit. & Phil. Soc., vol. LIV, pt. 3, 1910, p. 11, pl. IV, fig. 7; HICKSON, Trans. Linn. Soc., London, Zoology, 1911, Ser. 2, vol. XIV, pp. 443—462, pls. XXX—XXXII; HERON-ALLEN and EARLAND, Trans. Zool. Soc. London, 1915, pt. II, vol. XX, p. 728; CUSHMAN, Proc. U. S. Nat. Mus., vol. LVI, 1919, p. 632; HERON-ALLEN and EARLAND, Bull. Soc. Sci. Hist. et Nat. de la Corse, Bastia, 1922, pp. 139—140, Pl. II, figs. 40—49; HERON-ALLEN and EARLAND, Brit. Antarctic ("Terra Nova") Expedition, Zoology, vol. VI, n° 2, pp. 221—226, Pl. VIII, figs. 1—31, 1922; CUSHMAN, Carnegie Instit. Washington, Marine biology, vol. XXI, 1924, pp. 46—47.

Stat. 16. 6° 59′ S., 115° 24′.7 E. Depth 22 m.
Stat. 47. Bay of Bima; near south fort. Depth 55 m.
Stat. 49a. 8° 23′.5 S., 119° 4′.6 E. 69 m.
Stat. 51. Madura bay and other localities in the southern part of Molo-strait. From 69—91 m.
Stat. 59. 10° 22′.7 S., 123° 16′.5 E. 390 m.
Stat. 65a. 7° 0′ S., 120° 34′.5 E. From 400 m.
Stat. 66. Bank between islands of Bahuluwang and Tambolungan, south of Saleyer. 8—10 m.
Stat. 80. 2° 25′ S., 117° 43′ E. From 50—40 m.
Stat. 108. 6° 10′.3 N., 121° 32′ E. 73 m.
Stat. 144. Anchorage north of Salomakiëe-(Damar-)island. 45 m.
Stat. 153. 0° 3′.8 N., 130° 24′.3 E. 141 m.
Stat. 154. 0° 7′.2 N., 130° 25′.5 E. 83 m.
Stat. 157. 0° 32′.9 S., 130° 14′.6 E. 45 m.
Stat. 166. 2° 28′.5 S., 131° 3′.3 E. 118 m.
Stat. 189. 2° 48′.3 S., 127° 13′ E. 2124 m.
Stat. 204. 4° 20′ S., 122° 58′ E. From 75—94 m.
Stat. 240. Banda-anchorage. From 9—45 m.
Stat. 257. In Du-roa-strait, Kei-islands. Till 52 m.
Stat. 260. 5° 36′.5 S., 132° 55′.2 E. 90 m.
Stat. 274. 5° 28′.2 S., 134° 53′.9 E. 57 m.
Stat. 289. 9° 0′.3 S., 126° 24′.5 E. 112 m.
Stat. 305. Mid-channel in Solor-strait off kampong Menanga. 113 m.
Stat. 310. 8° 30′ S., 119° 7′.5 E. 73 m.

Description:

Mostly pink-coloured individuals, with two extreme forms in the megalospheric generation, the one having a broad base, with volcano-like projecting parts, which often grow into trees with twigs, the other with a narrow base, growing into a large single trunk and forming fan-like branches. Microspheric individuals also consist of a single tree with narrow base and a very pale colour.

The surface of the base and the stem is pock-pitted, owing to the openings of "pillars", outgrowths of the foramina of chambers, lying beneath the chambers which form the surface of the shell. Between the pits the chamberwalls show pores (not foramina, as HICKSON mentioned) with a diameter of about 5 μ. Under the surface there is a series of laminae having foramina similar to those of the surface lamina, connected by hollow "pillars", the walls of which are double and without any perforation. At the base these pillars communicate by a single foramen and by pores with the chamber close under it. In the middle of the stem are irregularly twisting tubes without perforated walls, beginning at the base of the individual, near the initial chambers, and ending at the tops of the branches with free mouths.

The initial chambers of megalospheric individuals generally show the raspberry-type, but it also occurs that there is a short spiral. The microspheric apparatus is always a spiral.

Much has been published about this species, but only few authors deal with the inner

structure of the shell and the protoplasm, and consequently its systematical place is still very uncertain. The authors who have published something about the inner structure of the shell are CARPENTER (1862), MÖBIUS (1880), MERKEL (1900), LISTER (1903), HICKSON (1911) and HERON-ALLEN and EARLAND (1922, Terra Nova).

I will first show in what respect I differ in opinion about some problems, already discussed in the quoted papers; in all other questions I have the authors' views or the ideas, exposed in the cited publications, have already been contested by other authors.

CARPENTER (1862) established that *Polytrema* shows some relation to *Tinoporus* and to *Carpenteria*, but supposed that it is "one of mere isomorphism, as we have seen the internal structure of the two organisms to be essentially different". As I will show, these species are more related than CARPENTER suggested.

MÖBIUS (1880) described the pillars as "Kammergänge", which in some respects is quite right.

MERKEL (1900, p. 297) observes that there is some correlation between the development of the trunk and that of the base. At first sight two forms are really found in the Siboga-material: the one has a flat and large base, covered with fine pores and larger sunk circular patches. Three or more volcano-like projecting parts, on the tops of which the large "central chambers" or central tubes open, are also seen in this form. But in more than one case these volcanoes are developed into thin-branched little trees (Pl. XII, fig. 2; Pl. XIII, fig. 6; Pl. XIV, figs. 3, 11). The other form has a little base and only one thick trunk arises in the middle of it, branching out at the top into boughs which are often, if not always, fan-shaped at the ends (Pl. XII, fig. 1; Pl. XIII, fig. 3; Pl. XIV, figs. 1, 2). In some of the samples are specimens, which have some characteristics of the one and some of the other form. All individuals belonging to these forms are megalospheric. It is obvious that here we have another example of trimorphism. Some of the tree-like specimens are very large and salmon-coloured; these individuals always have more than one embryonic apparatus; they are univalent [1]).

The chamber which MERKEL described as the initial one is decidedly the third and largest chamber. The very fact that three or more foramina are present in this chamber, described by MERKEL, speaks for itself: the initial chamber of all Foraminifera hitherto described has only one foramen. So I don't understand why MERKEL says: "Diese Kammer *a* ist als Embryonalkammer zu betrachten"; no motives are given for this idea.

In specimens of the megalospheric generation two kinds of initial chambers are to be found. The one, with small megalosphere (± 40 μ), has a sort of rotalid group of initial chambers, which slowly increase in size and the third chamber of which is not the largest (Pl. XIII, fig. 4). Such an initial stage has been figured by LISTER [2]). Typical forms with large base sometimes possess this kind of initial chambers.

The other megalospheric form on the contrary (I mean the form with small base and big trunk, while the branches are almost fan-shaped) shows a much larger megalosphere in most cases (± 80 μ) and the structure of the embryonic apparatus is that of a raspberry, as HERON-ALLEN and EARLAND already showed (1922). At first the globular megalosphere is followed by

1) HICKSON, S. J., On *Polytrema* and some allied genera (Trans. Linn. Soc., London, Zool., vol. XIV, pt. 3, 1911, Pl. 3, fig. 8).
2) LISTER, J. J., The Foraminifera in: Treatise on Zoology by RAY LANKESTER; pt. 1, fasc. 2, London, 1903, p. 122, fig. 51 C.

a chamber of somewhat the same size; the third chamber, however, has a bean-like shape; it is much larger and has nearly twice or three times the size of the megalosphere itself (Pl. XII, figs. 4, 5; Pl. XIII, fig. 1; Pl. XIV, fig. 4). In most cases the long axis of this chamber forms a cross with the two elder chambers and therefore I believe that HERON-ALLEN and EARLAND meant this large chamber when they said (1922, p. 222): "The smallest specimens observed in the free state are flattened and consist of four chambers, two of them of comparatively large size, apparently connected with one another by an intermediate neck".

The following chambers have already sufficiently been described by other authors. Some of them, constituting the base and the outer layers of chambers of the trunk, form the typical net-like chambers with pores and "pillars" (Pl. XIV, fig. 5), while one or two chambers of irregular shape and with brown or yellow coloured primary walls, develop into the large "central chambers", or, strictly speaking, into the central tubes of the trunk and branches. These tubes have a very typical shape, being broad at their base and growing thinner at the end. I believe them to be homologous with the outgrowths of the chambers of some Carpenteriae[1]). These outgrowths at early stages project freely outwards, but are afterwards overgrown with the flat chambers, so accurately described by MERKEL. The tops of the tubes open peripherically, forming a large mouth through which food, such as parts of sponges and diatoms, is thrown into the inner parts of the shell (Pl. XIV, fig. 11).

As to the net-shaped chambers, amply described by MERKEL, I wish to add the following remarks. BÜTSCHLI already mentioned that the pillars of these chambers possess at their base a foramen, larger than the pores of the chamberwalls and opening into the chamber upon the wall of which the pillar is based. Every pillar is connected in this way with the underlying chamber and not with the intralaminar spaces, as HICKSON thought. In most cases the foramen at the base of the pillar does not open into the centre of it but at the edge, formed by the wall of the pillar and the chamberwall. So it is obvious that the pillars are the beginning of new chambers, formed by the protoplasm streaming out through the foramina of the underlying chamber, and it is not true, as MERKEL says, that these pillars arise in this way, viz. that the chambers sink down in some places and "die eingesenkte Stelle sich auf die unter ihr liegende Wand aufsetzt" (MERKEL, p. 306). As in most cases, when afterwards the following chamber is covering the preceding one, the distal mouths of the pillars are closed by perforated walls, it is also possible that these pillars must be looked upon as much enlarged foramina of the first chamber (Pl. XII, fig. 6). Besides one should bear in mind that the next chamber, built on the surface of a chamber which opens with pillar-pores, is not the chamber which is connected with these pillars, but that it is the space through which these pillars force their way. So it is clear that the walls of this chamber also cover the openings of the pillars of the preceding chamber and that on the surface of this next chamber the pillars which pierce through it open freely outwards. So in most cases we do not find any trace of perforated walls, closing the pillars on the surface of a *Polytrema* (Pl. XIII, fig. 7). One can also understand that the walls of the pillars are double: the inner wall is the pillar-wall itself, formed by the protoplasm which streamed out of the foramen at the base of the pillar, the outer wall has been formed

1) HERON-ALLEN, E. and EARLAND, A., British Antarctic ("Terra Nova") Exp., Zool., vol. VI, n° 2, pt. II, 1922, Pl. VIII, fig. 14.

by the protoplasm of the next chamber, surrounding the pillar (Pl. XIII, fig. 2). These double pillar-walls prove that the pillars belong to the underlying chamber and not to the chamber lying upon that which surrounds the pillars, as MERKEL thought.

It is obvious that the perforation of the walls which close the distal ends of the pillars cannot be of any systematical value, as the pillars generally open freely at the periphery. So only the existence of the pillars and the perforation of the walls which surround the openings of the pillars can be used as characteristics to distinguish the species (see in this connection the description of the genus *Polytrema* by HICKSON, 1911, p. 445).

The chambers surrounding the initial ones do not possess the pillars and communicate only by normal foramina, as MERKEL described.

The microspheric apparatus has already been described by MERKEL and has also been found by HERON-ALLEN and EARLAND [1]) (Pl. XIV, fig. 8). I have been fortunate enough to find more than one microspheric individual, all of a considerable size, forming high, very rarely branched trees with narrow base, and of a very pale pink colour (Pl. XII, fig. 3; Pl. XIII, fig. 5) [2]).

VI. Genus **Homotrema** Hickson.

The characteristics are those of the species *Homotrema rubrum* (Lamarck).

1. *Homotrema rubrum* (Lamarck). Pl. XIII, figs. 8, 9; Pl. XIV, figs. 12—20; Pl. XV.

Millepora rubra Lamarck, Animaux sans Vertèbres, vol. 2, 1816, p. 202.
Polytrema rubra Carpenter, Parker, and Jones, Introduction to the study Foram., 1862, p. 235, Pl. XIII, figs. 18—20.
Homotrema rubrum Hickson, Trans. Linn. Soc., London, Zool., vol. 14, 1911, p. 454, Pl. XXX, fig. 2; Pl. XXXI, fig. 9; Pl. XXXII, figs. 19, 22, 28; HERON-ALLEN and EARLAND, Trans. Zool. Soc., London, vol. 20, 1915, p. 729; CUSHMAN, U. S. Nat. Mus., Bull. 100, 1921, vol. 4, p. 364.

Stat. 37. Sailus ketjil, Paternoster-islands. Depth 27 m. and less.
Stat. 65a. 7° 0′ S., 120° 34′.5 E. From 400 m.
Stat. 71. Makassar and surroundings. Up to 32 m.
Stat. 81. Pulu-Sebangkatan, Borneo-bank. 34 m.
Stat. 91. Muaras-reef, inner side: east coast of Borneo. Up to 54 m.
Stat. 144. Anchorage north of Salomakiëe (Damar) island.
Stat. 158. 0° 43′.5 S., 129° 56′.5 E. 391 m.
Stat. 225. 5700 m. N., 279° E. from southpoint of South-Lucipara-island. 894 m.
Stat. 274. 5° 28′.2 S., 134° 53′.9 E. 57 m.
Stat. 282. 8° 25′.2 S., 127° 18′.4 E. 27—54 m.
Stat. 303. Haingsisi, Samau-island. Up to 36 m.
Banda.

Beautiful specimens, especially forma A_1, have been collected by Dr. BOSCHMA at Edam, near Batavia.

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1) HERON-ALLEN, E. and EARLAND, A., l. c., 1922, fig. 29.

2) CARTER (On the locality of *Carpenteria balaniformis*, with description of a new species and other Foraminifera found in and about *Tubipora musica* [Ann. Mag. Nat. Hist. Series 4, vol. XIX, 1877]) gives a short description (p. 214) and two little, very doubtful figures (Pl. XIII, figs. 14 and 15) of *Polytrema miniaceum*, var. *album*; one of the figures deals with a microspheric specimen, the other is typically megalospheric. The description is somewhat misleading, so I cannot say whether CARTER saw a real *Pol. album* or met with a microspheric *Pol. miniaceum*, which also has a pale colour.

Features of the species:

Surface marked by defined areolae having small pores. The boundaries of the areolae are solid. These areolae are the only places showing perforations; underneath their thin walls run large passages forming an irregular mass of chamberlike hollows.

A_1. Short red trunks with thick stem and short branches. First set of chambers a short irregular spiral.

B. Probably dark-coloured crusts showing crater-like mouths; without branches. At first a spiral of chambers followed by irregularly growing stoloniferous chambers.

A_2. Tree-like red individuals with a blunt set of branches. Areolae arranged in rows along the stem and branches. First chambers forming a loose raspberry.

There are no reasons (as I will show) to place *Homotrema* in the neighbourhood of *Polytrema*, and yet, on the other hand, there are several indications that this species belongs to the TINOPORIDAE-group. I placed it at the end of this group. However it must not be thought that this arrangement is a very natural one, for I do not believe that there is any near relation between *Polytrema* and *Homotrema*, as SYDNEY J. HICKSON does. Its place so near *Polytrema* is merely a traditional one (I could examine some specimens of *Homotrema* from the North coast of Borneo, kindly sent to me by Mr. HICKSON).

I distinguish three forms of *Homotrema*, one of them is plurivalent, the other two are megalospheric. Between these megalospheric forms (Pl. XV, figs. 3 and 4) there was so little difference that I did not hesitate to look upon them as to be one and the same species. There are only three or four differences between them. The one, having a large first chamber (60 μ), surrounded by other chambers, as is the case in *Polytrema* ("raspberry"-shape, Pl. XV, fig. 5; Pl. XIV, fig. 16), has a salmon-red colour, figured by HICKSON (1911, Pl. 30, fig. 2). On a rather small base arises a stout column, the top of which is broadened into a crown terminating in short, often fan-shaped arms (Pl. XV, fig. 4; Pl. XIV, figs. 13, 20). The surface of the whole shell is marked by a large number of small foramina, $\pm$ 1 μ in diameter, combined into irregular fields. These fields are surrounded by solid boundaries, without foramina, and of a darker colour (Pl. XIII, figs. 8, 9). On the trunk of the little tree the fields which form areolae are much more regular than on the crown. These regular areolae, separated by solid shellsubstance, which are nothing but the chamberwalls, have always been found in the two other forms of the species. The other megalospheric form has always a deep purplish colour with more flattened base, on which one or more small pillars are erected (Pl. XV, fig. 3; Pl. XIV, fig. 4). The latter may be separated from each other or grown together with their bases. The embryonic apparatus is of a different shape; it begins with a smaller first chamber (36 μ) and is followed by an irregular spiral, while the raspberry is never found (Pl. XV, fig. 2).

Most of the individuals of the plurivalent form have a diameter of about 1 cm. and more and creep over the corals and stones like crust-mosses. The individuals form smooth crust-like covers, upon which are small rough outgrowths, only 1 or 2 mm. high, abruptly broken off

at their tops, giving to the whole its moss-like shape (Pl. XV, fig. 1). Most of these individuals are megalospheric, but now and then some of them show a spiral embryonic apparatus, as if it were microspheric. I am not sure I met with single microspheric specimens, but it is possible that some of these big colonies are microspheric; there was no material enough to state this. Some young attached shells with deep red colour showed a rotaline initial set of chambers, followed by irregular stolones. There is some possibility that they are microspheric specimens of *Homotrema* (textfig. 6).

The inner structure is a very typical one; it has nothing to do with that of *Polytrema*, but looks very much like the inner chambers of a stock of *Sporadotrema*. The chambers have the shape of an irregular cylinder, having at each end two or more large foramina which connect them with other chambers. Often they form only irregular clews, but in some cases layers may be formed which in some degree resemble the layers of chambers which occur in *Polytrema* (Pl. XIV, fig. 18). On examining the chamberwalls of the inner part of the shell, one will never find any indication of pores. Only the outer layer of chambers, which often radiate to the surface and thus form the regular network of chamberwalls on the surface we mentioned already above, is separated from the outer world by means of a very thin, flat wall, pierced by pores (Pl. XIV, fig. 19). These walls being only on the surface of the shell, it is obvious that during the time when the animal is growing, these walls must be resorbed again. One can often see the rudiments of these resorbed walls (Pl. XV, fig. 3).

Textfigure 6. *Homotrema rubrum.*
Decalcified young specimen of microspheric form.

At the tops of the branches and, in case there are no branches, in the centre of the individual, there are no perforated walls and the chambers open freely, forming in this way a kind of mouth, as is the case in *Sporadotrema*.

Family ROTALIIDAE.

I. Subfamily Rotaliinae.

The genera *Rotalia*, *Calcarina*, *Baculogypsina*, *Arnaudiella* and *Pellatospira* form a very distinct family with its remarkable canalsystem. When adding to it the subfamily of the Polystomellinae, we may distinguish in this family the subfamilies of Rotaliinae, Calcarininae and Polystomellinae.

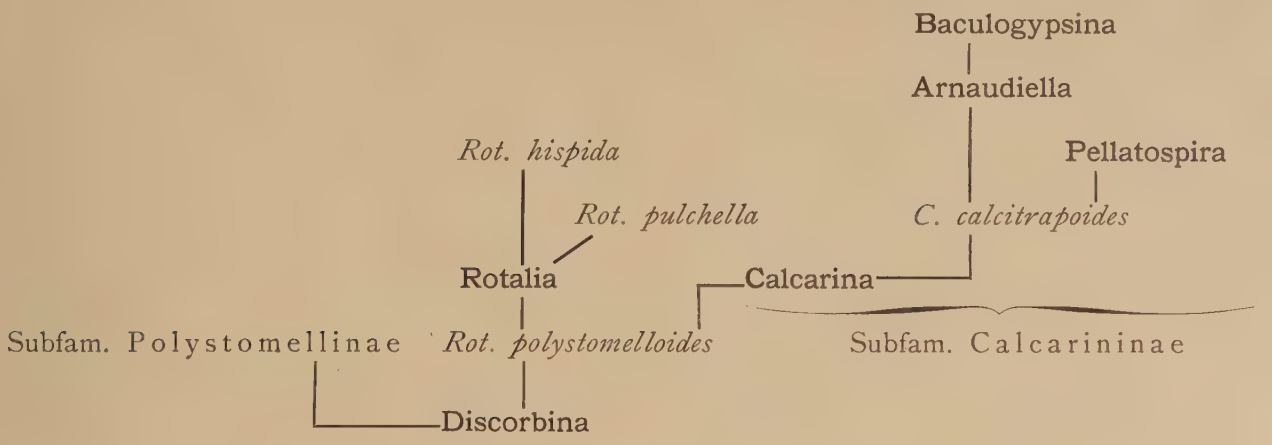
So I here break with the custom to place in this family also the Tinoporinae (in this work classed together with *Planorbulina*, to form the TINOPORIDAE), the Spirillinae, *Patellina*, *Cymbalopora*, *Discorbina*, *Truncatulina*, *Anomalina*, *Carpenteria*, *Rupertia*, *Pulvinulina*, as all these genera miss a canalsystem. For it is wrong to suppose that only lower Foraminifera lack a canalsystem and that this system should be a system of cavities, only due to the high development of the shell. The canalsystem also occurs in the lower representatives of the family and forms a very essential part of the generic and even family characteristics.

In most species there is a typical spiral of chambers for the later formed coils form alar prolongations on one or two sides, which in their turn form deep umbilici. These umbilici are filled up with secondary chalkmaterial in which canals are running. From a spiral canal under the spiral of chambers spring umbilical canals which form a network and interseptal canals and give rise again in the highest development to forking canals, opening at the dorsal sutures of the chambers. The chambers form ventral lobes which open into the spiral canal and in lower forms also possess pores ventrally. The spiral canal opens in the neighbourhood of the mouth of the shell at the umbilical margin of the last chamber with a mostly very narrow split. It was first discovered by HERON-ALLEN and EARLAND in the species *Discorbina polystomelloides* (1915, p. 699 [1]): "and there is a single large common shaped aperture placed on the inferior side of the shell at the umbilical edge of the last chamber of the secondary series"), but it has been wrongly interpreted by these authors, as they thought there was a second row of chambers in this species, which however is not the case.

In Polystomellinae the canalsystem is double, as on both sides an umbilicus is present.

1) HERON-ALLEN, E. and EARLAND, A., The Foraminifera of the Kerimba Archipelago (Trans. of the Zool. Soc. London, vol. XX, Pt. II, 1915).

Scheme of the suggested relations of the species and genera of ROTALIIDAE:



Genus **Rotalia** Lamarck.

This genus cannot be clearly distinguished from the genera *Discorbina* and *Pulvinulina*, without mentioning the canalsystem. This system which does not occur in *Discorbina* nor in *Pulvinulina*, must be looked upon as the most characterising feature of *Rotalia*.

So we can take the characteristics, as described by CUSHMAN [1]), and must add a description of the canals, already mentioned above: "Test free, composed of numerous chambers arranged in a flattened spire, biconvex or varying from flat above and convex below to convex above and flattened below; all chambers visible from the dorsal side, only those of the last formed coil visible from below; the umbilical region usually filled with clear shell material; surface variously ornamented with raised bosses or costae, or smooth and unornamented; aperture a single curved opening towards the periphery on the ventral side of the chamber". In most species the pores are very fine, only *Rotalia polystomelloides* shows coarser pores; it is therefore possible that this species forms a type, most related with *Calcarina* which always shows coarse pores. There is, however, a very distinct difference between *Rotalia* and *Calcarina*, the pores in the latter in all species melting together; besides *R. polystomelloides* is lacking spines. These spines, however, in a very primitive form, are present in *R. pulchella*. This species possesses simple, very fine pores. So it is here that the line between these two genera lies.

1. *Rotalia polystomelloides* (Parker et Jones). Pl. XVI, figs. 1—6.

Discorbina polystomelloides Parker and Jones, 1865, Phil. Trans., vol. CLV, p. 421, pl. XIX, fig. 8, *a, b, c*; BRADY, 1884, Challenger Report, p. 652, Pl. XCI, fig. 1 *a, b, c*; HERON-ALLEN and EARLAND, 1908, 1911, p. 330; 1914—15, Pl. LII, figs. 19—23, p. 698—700.

Stat. 58. Anchorage off Seba, Savu; up to 27 m.; 4 specimens.

Brief characteristics.

Only forma A_2 known.

Shell with lobated circumference; chambers of the last coil somewhat

1) CUSHMAN, J. A., An introduction to the morphology and classification of the Foraminifera (Smithsonian Misc. Collection, vol. 77, n^0 4, 1925, p. 46).

swollen up. Dorsal side with more than last spiral visible, with secondary chalk on the sutures, with openings of the canalsystem, separated by bridges of chalk. Ventrally the chambers of the last coils form ventral lobes, opening into the spiral canalsystem, but so well developed that these lobes reach the surface and seem to form a second row of chambers. The pores are coarse, aperture at the base of the last chamber; on the ventral side the opening of the spiral canal.

This *Rotalia*, described by other authors as *Discorbina*, shows very remarkable features which throw a clear light on the organisation of higher *Rotaliae*. The fact that this "*Discorbina*" possesses a perfect canalsystem which shows no differences with that of *Rotalia*, while the shape of the chambers is at all events that of this genus, made me suppose that *Discorbina polystomelloides* is rather a *Rotalia* than a *Discorbina*.

I only found in the Siboga-material four specimens, from Station 58. They are all of megalospheric form, and with respect to their outer structure and shape I can refer to HERON-ALLEN and EARLAND, 1915 [1]), and to Pl. XVI, figs. 1 and 2. The inner structure has not yet been fully understood. There has always been the idea, that a secondary set of chambers in the umbilical region of the shell, filling up the ridges between the superior series of chambers, would be present. Yet this secondary row in reality does not exist. In order to explain the real structure of this peculiar shell, I will describe it shortly.

There is a spiral of about 14 chambers with somewhat rounded sutures, which may be observed in all three convolutions on the dorsal side. These chambers show at their edge, just ventrally between the two foramina which communicate with the next chambers, a highly developed prolongation to the ventral side (fig. 3, *a*), building ventrally from each chamber a lobe, which on one side fills up the ridge between two chambers (fig. 3, *c*), on the other hand forms a short stolon, opening into the umbilical spiral canal (fig. 3, *b*). The lobes show the same coarse pores as are also found in the other parts of the chamberwalls. These lobes are blind ones; so they have no ventral porus in their outer wall, as HERON-ALLEN and EARLAND suggested. These pores belong to the umbilical canalsystem. This system consists of a typical rotaline spiral canal beneath the rows of chambers giving rise to two kinds of canals (fig. 4). One series of these umbilical canals, each of which begins exactly under each of the chambers, runs straight off to the ventral side and opens just between two opposite chambers and quite near to the ending of a ventral lobe (fig. 5, *a*). These openings are those figured by HERON-ALLEN and EARLAND. Some of the pores of the ventral lobes of the chambers communicate accidentally with these canals. Each of the second set of canals runs from the spiral canal between the chambers; they form the interseptal system (fig. 3, *d*), and give rise to four or five short canals, opening at the sutures. The openings, just as in all other species of the rotaline group, especially in *Polystomella*, are separated by bridges of chalk-material. The interseptal and the spiral canals show the typical compressed shape of all rotaline forms. The ventral lobes of the chambers form the so-called "secondary chambers" of this wonderful creature; so it is

1) HERON-ALLEN, E. and EARLAND, A., The Foraminifera of the Kerimba Archipelago. Part II (Trans. Zool. Soc. London, 1915, vol. XX, p. 699).

not true, that "no opening into the large chambers of the primary or superior series is shown", as HERON-ALLEN and EARLAND suggested. As I already mentioned, there is a narrow opening of the spiral canal on the inferior side at the umbilical edge of the last chamber (fig. 1, *a*). This canal-opening also exists in other *Rotaliae* and *Calcarinae*, but here it is often hidden by bosses of secondary chalk-material.

In *Rotalia* as well as in the genus *Calcarina* we shall meet with the same structure of the shell in all species. Here, too, the chambers show their ventral lobes which do not reach the surface (which in most cases is due to the fact that the umbilicus is hollower), but always give rise to the outgrowth to the spiral canal. The first mentioned set of canals, opening ventrally, is met with on higher organised *Rotaliae*, and builds the umbilical network. As in these Rotaliae, the umbilicus is very wide and shallow, the canals reach the surface mostly without forming a network. But I sometimes found that they anastomose even here.

2. *Rotalia pulchella* d'Orbigny. Pl. XVI, figs. 7—10.

Calcarina pulchella d'Orbigny, 1839, Foram. Cuba, p. 92, pl. V, figs. 16—18.
Rotalia pulchella Parker and Jones, 1865, Phil. Trans., vol. CLV, p. 387; BRADY, 1884, Challenger Report, p. 710—711, Pl. CXV, fig. 8, *a*, *b*.

Stat. 58. Anchorage off Seba, Savu; depth up to 27 m.
Stat. 77. 3° 27′ S., 117° 36′ E. Borneo-bank. Depth 59 m.

It has also been found in somewhat larger quantities by Dr. H. M. E. SCHÜRMANN in mud, dredged in the bay of Balik-Papan, 1925.

This species seldom occurs in the Siboga-material, Stations 58 and 77. It shows most characteristics of the *Rotaliae*, but some are positive characteristics of *Calcarina*. It is, as BRADY says, a beautiful little species, with its three tall slender spines. These spines are not, as BRADY mentioned, solid, but a rough canal runs through the centre of each spine. This canal originates in the umbilical system (the spiral canal especially), and each convolution forms one spine. Here and there in the spine little canals branch off but they are rare. Between the double septa of the chambers run the interseptal canals from which spring canals to the periphery. These canals are separated at their openings by chalk bridges, and often protuberances of chalk are formed in the neighbourhood of their mouths. On the ventral side the umbilicus is filled up with a single bead of chalk, around which the openings of the network canals which are of the same structure as those of *R. polystomelloides* are found. These canals communicate with a very well developed spiral canal, into which run the ventral lobes of the chambers, which are very well developed, but only occasionally reach the ventral side of the shell. Though the spines communicate with the umbilical canalsystem, the shape of the chambers and the narrow pores, which never melt together, show the relation with *Rotalia* rather than with *Calcarina*.

3. *Rotalia calcar* (d'Orbigny). Plate XVII.

Calcarina calcar d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 276, n° 1; in DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, 1839, p. 93, pl. 5, figs. 22—24.
Rotalia calcar H. B. Brady, Rep. Voy. Challenger, Zool. vol. 9, 1884, p. 709, pl. 108, figs. 3, 4?; CUSHMAN, Bull. 71, U. S. Nat. Mus., pt. 5, 1915, p. 69, pl. 28, fig. 2, pl. 29, fig. 2; CUSHMAN, Bull. 100, U. S. Nat. Mus., vol. 4, 1921, p. 350, pl. 71, figs. 3*a*, *b*.

Calcarina calcar var. *hispida* Carter, Ann. Mag. Nat. Hist., ser. 5, vol. 5, 1880, p. 453.
Calcarina hispida H. B. Brady, Rep. Voy. Challenger, Zool., vol. 9, 1884, p. 713, pl. 108, figs. 8, 9.

In some samples this species was very abundant, especially in the collection of shore-sand, gathered by Toxopeus (1925) at Buru. The stations of the "Siboga" at which specimens were found in some quantities are:

Stat. 99. 6°7'.5 N., 120°26' E., depth 16—23 m.
Stat. 127. Taruna-bay, Great-Sangir-Island, depth 45 m.
Stat. 133. Anchorage off Lirung, Salibabu-island, up to 36 m.
Stat. 164. 1°42'.5 S., 130°47'.5 E., depth 32 m.

Most striking characteristics of the species.

Forma A_1. Individuals identical with forma B, but not so large. The whole shell covered with spinous buds of secondary chalk, no canals in these spines; chambers swollen up.

Forma B. Individuals somewhat larger, covered with a mass of little spinous buds on the chambers. Chambers more swollen up, ending in a sharp spine. Pores much finer than those of *Calcarina*. Diameter up to $1^1/_2$ mm.

Forma A_2. Dorsally all coils of the chambers are visible, ventrally a secondary chalk mass covers the umbilical region. Sutures also filled up with smooth chalk. Each chamber of the last coil ending in a blunt spine. Canalsystem typically rotaline, without spines formed by canals.

In nearly all samples in which *Rotalia calcar* was found, also *Calcarina hispida* occurred. I found by means of my canadabalsam-method that *C. hispida* does not differ from *R. calcar*, except in the development of the chalk-spicules on the surface, and consequently also with respect to the form of the chambers, the latter characteristic being a difference in surface-tension, probably due to the greater quantity of chalk in the protoplasm. I was able to find some microspheric individuals which I believe to belong to the same genus. These forms have the characteristics of *C. hispida*.

The typical *Calcarina hispida* and *Rotalia calcar* which show many intermediate forms are always of the megalospheric generation. I do not know whether *C. hispida* or *R. calcar* has the greater first chamber; its diameter is 30—60 μ. The first spiral of chambers is typically rotalide; the chambers are somewhat triangular-shaped (figs. 7, 11). In the last coil the chambers in some cases show long elongations, in this way forming the "spines". These spines have nothing to do with those of *Calcarina* which always find their beginning in the canals between two chambers, and are never built as a lengthening-piece of a chamber. Yet the "spines" of *Rotalia hispida* are built with the help of the outgrowth of the canalsystem, the canals which run between the chambers to the circumference of the shell, bending sideways and opening into several little pores on the sides of each spine, just as is the case in *Baculogypsina* (= *Siderolites*) *sphaerulata* (fig. 12).

The canalsystem beginning with a spiral under the first coil of chambers (fig. 12) forms branches, each of which runs between two chambers and bifurcates before reaching the surface,

a typical rotalide characteristic. From this first spiral branches run down into the supplemental skeleton which fills up the umbilicus (fig. 10). Within this umbilicus secondary pillars of clear chalk-substance are formed (fig. 11) between which the canals form an irregular network before reaching the surface and forming branches towards the spines on the older chambers. In the *calcar*-types the chambers of the last coil narrow directly into the spines, which are often somewhat directed towards the mouth of the chamber, giving to the whole building the shape of a screw. In the *hispida*-forms, on the contrary, the chambers are more swollen up and the spines form only a little part of the volume of the chambers. Another typical feature of the *hispida*-type is the development of little spines in all places, where pores or canals open on the surface. These spines bifurcate and are branched out more than once, but are never hollow. So it is obvious that these spines are only due to the great quantity of chalk in the protoplasm; an individual of the hispid form, without its short little spines, cannot be distinguished from "*Rotalia calcar*". The most important characteristic which immediately shows the relation of *Rotalia calcar* and "*Calcarina*" *hispida* to the real *Rotaliae* lies in the absence of any secondary dorsal canalsystem, which forms, as we shall show further on, such a typical characteristic of the *Calcarinae*. Firstly the pores of the chambers are in the two forms of *Rotalia hispida* of a finer shape than is the case in any *Calcarina*-species. Secondly the dorsal pores never run into canals which direct to the surface, but open into the water. Here we also have a difference between hispid forms of *Rotalia hispida* and hispid forms of *Calcarina mayori*.

The third form has the typical shape of the *hispida*-type, only the diameter is greater (up to 2 mm., whereas the diameter of the megalospheric form is only ± 1 mm), the chambers in each coil are more compact, their number being larger, and the first chamber measures only about 20 μ. This form in its highest development can scarcely be distinguished from the microspheric form of *Calcarina defrancei*, except its having "spines" formed by the chambers of the last coil only, the latter having typical *Calcarina*-spines, which begin in the centre of the shell.

4. *Rotalia schroeteriana* Parker et Jones. Pl. XVIII and XIX; Pl. XXI, figs. 1, 2, 7, 11 and 13.

Faujasina sp. Williamson, 1853, Trans. Micr. Soc. London, Ser. 2, vol. I, p. 87, pl. X, figs. 1—6.
Rotalia schroeteriana Carpenter, Parker and Jones, 1862, Introduction to the study of the Foram., p. 213, pl. XIII, figs. 7—9; BRADY, 1884, Challenger Report, Zool., vol. 9, p. 707, pl. CXV, fig. 7; CUSHMAN, 1921, U. S. Nat. Mus., Bull. 100, vol. 4, p. 347, Pl. 73, figs. 1*a*—*c*.
Rotalina schroeteriana Egger, 1893, Abh. Kgl. Bayer. Akad. d. Wiss. München, II. Classe, vol. XVIII, pt. 2, p. 422, pl. XIX, figs. 10—12.
Rotalia schroeteriana Flint, 1899, Recent Foraminifera ("Albatross"), pl. LXXVI, fig. 1; HERON-ALLEN and EARLAND, 1915, Trans. Zool. Soc. London, vol. XX, Pt. II, p. 719.

Two megalospheric specimens of this species have been found in the Siboga-material at Stat. 77 (3° 27′ S., 117° 36′ E.; depth 59 m.; Borneo-bank), while a beautiful collection from the East coast of Borneo was sent to me by Prof. Dr. K. GERTH. It was perhaps the same sample described by RUTTEN [1]) from the pliocene off Sg. Boesoe near Bontang. In 1925 Dr. SCHÜRMANN collected beautiful and numerous specimens in mud-samples from the bay of Balik-Papan.

1) RUTTEN, L., Studien über Foraminiferen aus Ost-Asien (Samml. des Geol. Reichs-Museums in Leiden, Ser. 1, vol. 9, 1914, p. 287).

Characteristics of the species.

Forma A_1. Test conical, with truncated top. This top consists of a flattened chalkmass, filling up the umbilicus and perforated by large canals. Rows of chalkbuds mark the sutures of the chambers. Diameter ± 1 mm.

Forma B. Test much more compressed and rounded at the edge. Umbilical chalkmass forming a large part of the ventral side. Chalkbuds very large and distinct. Diameter ± 2 mm.

Forma A_2. Nearly equal to forma A_1, but the dorsal side is somewhat rounded and the chalkbuds are more irregularly scattered on the surface.

Three forms have been met with, one of them possessing a diameter of about 2 mm., the other two one of only 1 mm. The smaller forms show the most typical resemblance with the specimen which CARPENTER (1862) figured (Plate XVIII, fig. 2). They show a conical shape and the dorsal side of one of the two forms is very flat, whereas the other form possesses a more convex dorsal face and a rounded periphery (Pl. XVIII, fig. 1). The latter is also the case with the larger form, which is more rounded, not so very conical (Pl. XVIII, fig. 3). Especially the latter two forms show a striking resemblance with the *Rotalia papillosa* group, and it is therefore possible that *R. papillosa* and *R. schroeteriana* are only varieties of the same species. A study of the inner structure of the shells brought to light that the large form is the microspheric one and the two others are megalospheric.

The microspheric generation is formed by comparatively compressed individuals, the diameter is to the height of the shell as 5 is to 2. There are ± 20 chambers in the last coil. The sutures show in some cases only the opening of canals (Pl. XVIII, fig. 3*b*), but in most individuals these openings are flanked by beads of chalk. "Aperture an arched cleft at the inner margin of the inferior face of the final segment near the periphery" (BRADY). On the dorsal side the chambers of the later rows are rather visible by means of the developed chalk-masses on the sutures; these beads are also found at the margin of the shell. Ventrally the umbilical region is filled up with secondary chalk, which forms a protuding plane on which the openings of numerous canals are seen. It is this form which has been figured by BRADY (Pl. CXV, fig. 7).

The megalospheric forms are much more conical, the diameter being to the height as 3 is to 2. The last coil is formed by only ± 12 chambers and the sutures are marked by rows of beads of chalk-material. The umbilicus is narrow but filled up with chalk, forming once more the flat top of the conus on which the openings of canals are easy to see. The margin of this protuding chalkmass is very distinct and follows the inner edges of the outer layer of chambers. The canalsystem of this species has already been studied by CARPENTER (1862) who gives a short description and two small but very accurate figures. This system can be divided into the umbilical and the interseptal system. These two systems are connected with one another by means of a spiral canal running in the umbilicus along the rows of chambers surrounding the umbilical space (Pl. XIX, figs. 3, 4, 9 and 12). This spiral shows a flattened shape in a transverse section. It is uncommonly well developed in microspheric specimens. So we see that this

building is a primitive one and seems to be one of the most characteristic things in the *Rotaliae*. It seems to me that HERON-ALLEN discovered it in "*Discorbina*" *polystomelloides* (1915, p. 698—700, pl. LII, figs. 22, 23), while showing, that the "secondary series of chambers" possesses an opening of its own and that these "chambers" are almost entirely enclosed in the test. The characteristics of these "chambers" can also be applied to the spiral canals of *Rotalia*, and looking from the ventral side into the umbilicus we see the same buildings as HERON-ALLEN figured from *Discorbina*. The spiral begins with interseptal spaces between and beneath the first chambers of the shell and soon forms a broad but flat spiral hole, which is formed when a new coil of chambers meets the outer margin of the protruding chalkmass which fills up the navel. So the spiral is situated just in the edge formed between the ventral ends of two coils of chambers. The aperture of the spiral is at the base of the last chamber.

From this spiral spring two kinds of canals. One of these systems is situated inside the spiral; we may call it the umbilical system (Pl. XIX, fig. 8, *a*). It forms an irregular network of canals (Pl. XXI, fig. 7), opening on the ventral side of the shell in the umbilical region.

The other system must be called the interseptal one (Pl. XIX, figs. 3, 4, 6, 8, *c*; Pl. XXI, figs. 1, 2, 13). Between two successive chambers of the same coil runs a canal from the spiral to the dorsal side of the shell which ends in a bifurcation just in the suture between this row of chambers and the following one or, as is the case in the last coil, at the margin of the shell. The ascending part of these canals forms a kind of interseptal fissure, as CARPENTER already described (p. 214), and forms secondary canals, some of which are running to the ventral sutures, while others run to the dorsal side of the shell (Pl. XIX, fig. 8, *c*). These secondary canals bifurcate again when a new layer of chambers overgrows the openings of these canals at the sutures, and in this way it is possible that canals, which at first opened into ventral sutures, later on end on the dorsal side of the shell. At the openings of the canalsystem chalk-substance is laid down, so as to form the beads of secondary chalkmass we mentioned already (Pl. XVIII, fig. 4).

There is some communication between the chambers and the canalsystem. Firstly each basal end of the chambers forms a prolongation which runs down into the umbilical or spiral canalsystem. This prolongation is the same thing that was mentioned in the description of *Rotalia polystomelloides*, and which in that species forms the so-called secondary set of chambers (Pl. XIX, fig. 1). Secondly the chambers frequently form a kind of secondary foramina which also communicate with the interseptal canals. The ends of the interseptal canals often communicate with the chambers by pores, which in this way do not run directly to the periphery but into the canals (Pl. XIX, figs. 2, 5 and 8).

The pores are very narrow, as is the case in most *Rotaliae*. With respect to the prolongations of the chambers running down into the umbilical system we remark that this phenomenon seems to be a characteristic due to the ventral development of the chambers, as it has been found in the same way in other Rotalids with ventral development. It seems to be like this: the protoplasmic substances streaming out of the next opening of the umbilical canal-system and those which stream out of the foramen of the last formed chamber mix and build up the next chamber; so the canalsystem may be an important factor in the building of chambers. In higher forms such as *Siderolites* the irregular growth of the chambers is in the first

place due to the canalsystem. It is possible that the great ventral development of the chambers occurring in most rotalian species is due to the high development of the umbilical canalsystem.

II. Subfamily Calcarininae.

This subfamily includes the genera *Calcarina*, *Pellatospira* †, *Arnaudiella* † and *Baculogypsina*. CUSHMAN [1]) has suggested that the senonian fossil *Calcarina calcitrapoides* Lamarck possesses secondary sets of chambers, as is the case in higher forms of Calcarininae such as *Baculogypsina*. I am not at all of the same opinion and in my paper on *Calcarina calcitrapoides* [2]) I showed that in this species other chambers than the spiraline ones do not occur, though the latter are equitant: *Calcarina calcitrapoides* therefore seems to be a real *Calcarina* and so there is no reason to keep the genus *Siderolites*; this is the reason why the recent species "*Siderolites*" *tetraëdra* (Gümbel) was considered to be a real *Baculogypsina*, as I will prove further on. It is possible that even the genus *Pellatospira* will appear to be a special form of a species of *Calcarina*, just as the species *Calcarina calcitrapoides* shows a spineless form. There are however some reasons to believe that the Foraminifera described by BOUSSAC [3]) under this name and considered by this author to be allied to *Assilina* are not the same as the specimens described by RUTTEN [4]). The latter are evidently some Calcarinae without spines, the pores being much coarser than those in the specimens of BOUSSAC. The genus *Arnaudiella*, only known in the species *Arnaudiella grossouvrei*, seems to me to form a link between *Calcarina calcitrapoides* and *Baculogypsina tetraëdra*.

Most important features of the subfamily Calcarininae: Shells mostly provided with spines, built up by a canalsystem beginning at the first whorls of the shell. Chambers in primitive species building a single spiral, but showing a tendency to overlap the former coils. Pores of the chambers very coarse and often opening into a canalsystem. In primitive forms blunt solid columns generally cover the surface, forming cavities between them which give rise in higher forms to the building of secondary chambers. These chambers, low in *Arnaudiella*, become more swollen-up in *Baculogypsina tetraëdra*, while in some forms of the latter they are arranged in radial rows. This phenomenon attains its highest development in *Baculogypsina sphaerulata*, where the chamberrows resemble those of *Tinoporus*, so that this species has for a long time been looked upon as the type-species of the latter genus. There are, however, two differences between *Tinoporus* and *Baculogypsina*: the former lacks a canalsystem and shows the raspberry-type in typical megalospheric forms, which *Baculogypsina* never does.

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1) CUSHMAN, J. A., Foraminifera of the Philippine and adjacent seas (U. S. Nat. Mus., Bull. 100, vol. 4, 1921).

2) HOFKER, J., Die Foraminiferen aus dem Senon Limburgens, I; *Calcarina calcitrapoides* Lamarck (Natuurhist. Maandblad, Maastricht, vol. 15, pt. 2, p. 14—17, 1926).

3) BOUSSAC, J., Développement et morphologie de quelques Foram. de Priabona (Bull. Soc. Géol. France, ser. 4, pt. 6, 1906, p. 88).

4) RUTTEN, L., Jaarb. Mijnwezen, 1915, vol. 44, Pl. III. — Ibid., Studien über Foram. aus Ost-Asien (Samml. Reichsmus. Leiden, vol. X, 1915—1923, Pl. II, figs. 1 and 2).

Genus **Calcarina** d'Orbigny.

This typical group of rotalian Foraminifera represents the intermediate forms between the genera *Rotalia* and *Siderolites*. Though some authors think that the members of this genus are not at all distinctly separable from true *Rotaliae*, I am sure that this supposition is wrong and due to the vague definition of the genus.

When we read BRADY's definition of the genus: "Test rotaliform; lenticular; periphery furnished with radiating (sometimes branching) spines; supplemental skeleton and canalsystem very largely developed", the following questions arise:

1) are there differences in rotaliformity between the shells of *Rotalia* and of *Calcarina*?
2) there are *Rotaliae* with spines; does there exist any difference between the spines of true *Rotalia* and of *Calcarina*?
3) what is the difference between the supplemental skeleton and canalsystem of *Rotalia* and *Calcarina*?

These questions have to be answered before a real definition of the genus can be given.

CUSHMAN's [1]) definition of the genus does not throw much light upon these questions: "Test composed of numerous chambers, close coiled, biconvex; periphery usually with radiating spines; chambers visible at least on the ventral side, sometimes on the dorsal side as well; aperture typically consisting of a row of small openings along the inner margin of the apertural face; supplemental skeleton and canalsystem highly developed".

As for the aperture I am of opinion that, though it may be a very good characteristic within the *Miliolidae* or the *Lagenidae*, it is of no value in the *Rotalidae*; in young specimens the aperture is much more primitively built than in older individuals and in some allied genera the difference between the forms of the aperture is very great, in others there is no difference at all. So *Rotalia hispida*, though not a *Calcarina*, possesses a complicated aperture. CUSHMAN's [2]) definition in 1921 is much better: "Test rotaliform throughout, chambers numerous, close-coiled, biconvex; periphery with radiating spines; chambers of the last formed coil visible on the ventral side, those of the dorsal side partially hidden by the supplemental skeleton which is more or less developed in all the species; aperture typically a row of small openings along the inner margin of the apertural face; canalsystem well developed". Here we find something about the dorsal supplemental skeleton which is doubtless an important systematical characteristic. There are, however, other questions mentioned by CUSHMAN in the same Bulletin, which must not be overlooked here. Firstly *Tinoporus* shows no relationship with true *Calcarinae*, so that only the genera *Calcarina* and *Baculogypsina* belong to the same group, whereas *Siderolites*, as I shall show further on, is a real *Baculogypsina*. Secondly the fossil species *Calcarina calcitrapoides* from the Senonian chalk of Maestricht does not at all belong to the genus *Siderolites*, as I have described elsewhere, but it is a real, though highly developed *Calcarina*; the secondary outgrowth of chambers roundabout the first spiral is a typical feature of *Baculo-*

1) CUSHMAN, J. A., A monograph of the Foram. of the north Pacific Ocean. (Smithsonian Inst., U. S. Nat. Mus., Bull. 71, pt. 5), *Rotalidae*, 1915, p. 71).

2) CUSHMAN, J. A., Foraminifera of the Philippine and adjacent seas (Smiths. Inst., U. S. Nat. Mus., Bull. 100, vol 4, 1921, p. 350).

gypsina, and does not occur in *C. calcitrapoides*, which possesses coils of chambers overlapping the older coils. It is not "much more complex than most of the species of *Calcarina*".

We will here give a more precise description of the genus *Calcarina*, based upon our own researches:

Test rotaliform, chambers numerous, especially in microspheric individuals, close-coiled; dorsally the chambers form a convex spiral, ventrally however they form a deep umbilicus, which is filled up with supplemental skeleton, so as to form a biconvex shell. The older chambers show a tendency to overgrow the first spirals, especially on the ventral side, but in some cases also on the dorsal one (*C. calcitrapoides*). The secondary skeleton is situated in the umbilicus and in the spines and forms a covering on the dorsal side. It is traversed by a canalsystem and the pores on the dorsal side of the chambers always open into this system, never directly outward. The spines are formed by chalk surrounding a peculiar system of canals, which begins in the ventral canalsystem. In this way the spines can be traced further to the centre of the shell and are never built by outgrowths of the chambers; they are of typical supplemental origin. Especially in microspheric forms the result may be a great development of the spines; they are fanshaped in that case and often grow into a kind of marginal border.

1. *Calcarina mayori* Cushman. Pl. XX; Pl. XXI, figs. 8 and 12.

Calcarina mayori Cushman, Samoan Foraminifera, Department of marine biology of the Carnegie Institution of Washington, vol. XXI, 1924, p. 44, Pl. 14, figs. 4—7.

Stat. 133. Anchorage off Lirung, Salibabu-island, depth up to 36 m.
Stat. 273. Anchorage off Pulu Jedan, East coast of Aru-islands; 13 m.
Leksoela, Buru, reef, abundant (Toxopeus leg., 1922).

Two forms have been found in the Siboga-material, and there are intermediate specimens among them. They are all of the megalospheric generation, the microspheric has not been met with. But it is very probable that the specimen, figured by CUSHMAN [1]), is nothing but a microspheric specimen, for in our specimens the megalospheric form with the smallest first chamber shows a very hispid character and the microspheric forms of all *Calcarinae* I have examined always show a carinate outgrowth of the spines (viz. *Calcarina calcitrapoides* and *C. Spengleri*).

This little species of *Calcarina* shows all the typical characteristics of the genus. The two forms I met with only differ in the development of secondary growth, the one having the characteristics of the individuals, CUSHMAN figured (Pl. XX, figs. 1 and 2), the other being much more hispid and very difficult to distinguish from *Rotalia hispida* (Pl. XX, figs. 3 and 4). The inner characteristics however are clearly distinguishable from those of the latter species: never are the spines built by the chambers themselves (Pl. XX, figs. 5 and 6); on the dorsal side the coarse pores always open into a canalsystem and never reach the surface (Pl. XX, fig. 10).

Typical form. Fullgrown test formed by 4 coils, last coil with ± 18 chambers, which are narrow and only the last 4 of which are blown up. On the dorsal side the spiral of chambers may be distinguished and in the centre 4 or 5 little hyaline columns of secondary chalk-mass are visible (Pl. XX, fig. 1). The spines are built up by fine tubercles, arranged in the direction

1) CUSHMAN, J. A., A monograph of the Foraminifera of the North Pacific Ocean (Smiths. Inst., U. S. Nat. Mus., Bull. 71, 1915, Pl. 31, fig. 3).

of the spine; most of them are blunt. On the ventral side the last coil of chambers forms the greater part of the shell, forming a relatively narrow umbilicus, which however is filled up with a convex mass of shell-substance (Pl. XX, fig. 7). Some specimens have no little spicules at all, others are just as CUSHMAN describes them. The first chamber possesses a diameter of about 40 μ and is surrounded by a relatively thick wall (Pl. XX, fig. 6). The length of the chambers of the younger coil is twice their breadth and the spines can be traced especially on transverse slides, to the centre of the shell (Pl. XX, fig. 7). The umbilicus is traversed by an irregular canalsystem surrounding the columns of clear shell-material (Pl. XX, fig. 12) and from these canals originate those which run through the spines, as is the case in real *Calcarinae* (Pl. XX, fig. 7). On the dorsal side, as already mentioned, the pores of the chambers run into canals, and these canals open outward (Pl. XX, fig. 10).

The hispid form shows a much greater development of secondary growth, so that the sutures of the first coils of the chambers are neither visible on the dorsal nor on the ventral side. The spines possess very long spicules (which are arranged like the branches of a pine) and so do the outer chamberwalls (Pl. XX, fig. 8). The first chamber has a diameter of about 30 μ (Pl. XX, fig. 5).

It is possible that some of the authors, dealing with *Calcarina defrancii*, have also met with the species *C. mayori*, though CUSHMAN says that it is entirely different from it. It is also possible that *C. defrancii* is not a *Calcarina* at all, but a real *Rotalia*. I did not meet with a typical *C. defrancii* in the Siboga-material. The latter species has been described very accurately by MÖBIUS [1]). His figures show us a mixture of *Calcarina*- and *Rotalia*-characteristics, so that it would be very interesting to study typical *defrancii*-material again. I believe that MÖBIUS examined *Rotaliae* and *Calcarinae* when describing and figuring this species. Perhaps *Calcarina* (or *Rotalia*) *defrancii* forms a link between the two groups. The pores of the chambers are too fine to belong to a *Calcarina*, but the spines are formed by secondary canals and not by the chambers. There is, however, no canalsystem on the dorsal side, except in the older coils. It is possible that MÖBIUS' figures of the pores are not always exact; in this case it would be a real *Calcarina*.

2. *Calcarina Spengleri* (Gmelin). Pl. XXI, figs. 3—6, 8—10; Pl. XXII.

Nautilus Spengleri Linnaeus, Syst. Nat., ed. 13 (Gmelin), 1788, p. 3371, n° 10.
Calcarina Spengleri d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 276, n° 4; CARPENTER, PARKER and JONES, Introduction to the study of the Foraminifera, 1862, p. 216—223, Pl. XIII, fig. 21, Pl. XIV, figs. 1—10, textfigs. XXXIII—XXXVI; H. B. BRADY, Rep. Voy. Challenger, Zool., vol. 9, 1884, p. 712, pl. 108, figs. 5, 7; CUSHMAN, U. S. Nat. Mus., pt. 5, 1915, p. 72, pl. 31, fig. 2; CUSHMAN, U. S. Nat. Mus., Bull. 100, vol. 4, 1921, p. 351—352, pl. 75, fig. 1.
Calcarina baculatus (?) (Montfort), Cushman, Bull. 100, U. S. Nat. Mus., vol. 1, pt. 6, 1919, p. 364, pl. 44, fig. 3; idem, U. S. Nat. Mus., Bull. 100, vol. 4, 1921, p. 354—355, pl. 75, fig. 3.

Stat. 125. Anchorage off Sawan, Siau-Island, depth 27 m.; rare.
Stat. 133. Anchorage off Lirung, Salibabu-island; depth up to 36 m.; abundant.
Stat. 220. Anchorage off Pasir Pandjang, West coast of Binongka, depth 278 m.; rare.
Leksoela, Buru, Exped. Toxopeus, 1922, very abundant.

1) MÖBIUS, K., Foraminiferen von Mauritius (Beiträge zur Meeresfauna der Insel Mauritius und der Seychellen, Berlin 1880, p. 104—105, Pl. XIV). The species is here described under the name of *Rotalia Defrancei* d'Orbigny.

Brief description of *Calcarina Spengleri.*

Forma A_1. Four or five coils of numerous chambers, later windings overlapping the former on the ventral side, so that a narrow umbilicus with few columns of secondary chalk-mass is formed. Last chambers swollen up. More than four spines, somewhat irregularly placed.

Forma B. Larger specimens with 8—10 fan-shaped spines, numerous columns scattered over the whole surface and without visible last chambers. Secondary chalk-mass very highly developed. Chambers very numerous and equitant on both sides of the shell.

Forma A_2. Specimens all with 4 large spines, chamberrows never overlapping on both sides, so that a large umbilicus with numerous columns is formed. Last chambers somewhat bloated [= *C. baculatus* (?) (Montfort) Cushman].

This species is the largest of the recent ones, with a diameter up to 2.5 mM. It is a very typical *Calcarina*, the later-formed coils of which have a tendency to overlap the preceding convolutions, especially on the ventral side. Three forms were found, two of them megalospheric, the other microspheric. Lister [1]) has given the diameter of the first chambers of the several forms of this species. He says p. 437: "The average mean diameter of the megalosphere in 12 specimens is 49 μ, the extremes being 58.5 and 38.5 μ. The microspheres in the 2 microspheric examples measure 15×12.5 μ and 13×11 μ". The two megalospheric forms pass into each other by means of intermediate forms. The one possesses chambers which overlap the preceding ones but slightly. In this way the canalsystem on the ventral side is very strongly developed and in this network a great many massive chalk-columns are built, projecting on the surface and forming very distinct wart-like protuberances (Pl. XXII, fig. 9). On the dorsal side, at the openings of the canals, lots of tubercles are formed in the same way; these tubercles are always situated on the sutures and arranged regularly (Pl. XXII, fig. 10). The second megalospheric form has a more lenticular shape; the chambers largely overlap the preceding convolutions on the ventral side (Pl. XXI, fig. 10, Pl. XXII, fig. 4), and form a narrow umbilicus. In this way only few columns are developed on this side (Pl. XXII, fig. 11). The periphery is rounded and the chalk-masses, having no room in the columns, form tubercles of chalk at the openings of the canalsystem and among the pores of the chambers, covering in such a way the whole surface with "small knobs or bosses with finer spines between". Only three or four spines are usually met with. This description agrees with that which Cushman gives of his *Calcarina baculatus* (?) (Montfort); so I am sure that this "species" is nothing but one of the two megalospheric forms of *Calcarina Spengleri,* the more so, as the latter species possesses a microspheric generation, which again shows the development of secondary chalk-masses on the surface of the shell. The microspheric generation was represented in the Siboga-material by only two specimens (Pl. XXII, figs. 6 and 7); one of them I have polished into a slide in order to show it was really microspheric (Pl. XXII, fig. 1.). The habitus of this form is identical with the individuals which Carpenter

1) Lister, J. J., Contributions to the Life History of the Foram. (Phil. Trans. Roy. Soc., London, vol. 186 B, p. 401—453, 1895).

(1862, Pl. XIV, fig. 2; textfig. XXXIV) describes as a proliferous Philippine variety; CUSHMAN mentions several forms of this kind, when he describes *Calcarina defrancii*. In the centre of the test the little microsphere is situated surrounded by a narrow spiral of little chambers, followed by six coils forming the rest of the shell. The chambers are narrow and relatively small; the secondary chalk-substance, on the contrary, is rather highly developed with its fine canal-system. The tubercles, which cover the surface, are spinous and sharp and even the spines are hispid. These tubercles on the spines sometimes develop and form the bifurcations of these spines, characteristic of the specimens. The bifurcations have a fan-like shape and the whole phenomenon shows the same characteristics that are found in microspheric *Calcarina calcitrapoides* (Pl. XXII, fig. 8).

In all forms the following characteristics may be met with. The canals of the spines originate in the umbilical canalsystem beneath the first coil of chambers, but the pores of neighbouring chambers also communicate with the canals of the spines (Pl. XXII, fig. 3). These spines can be traced through the whole shell to the first coils and this is the first difference between real *Calcarina*-species and the spinous Rotalians, the latter having spines formed by outgrowths of the chambers of the last coil. The second difference between them is the tendency of the *Calcarinae* to form equitant chambers, bestriding the chambers of the preceding convolution and reaching their highest development in *Calcarina calcitrapoides* of Maestricht.

The pores of the chambers of the last windings end in canals which, as the secondary chalk-mass on the surface grows thicker, unite and debouch into the broader cavities between the chalk-warts on the surface. The chambers of the first coil only communicate by means of a single foramen at the basis of the chamber, but afterwards a row of basal foramina between the neighbouring chambers is developed. Never do the pores of the chambers communicate with those of the following coils, but they always end in the canals. On the ventral side many of these canals form an irregular network round the massive columns (Pl. XXI, fig. 7), of which the middlemost is surrounded by the spiral canal underneath the first chamber and the first coil. Most of the canals which are formed by the pores of the chambers debouch into the chambers of the following coil and so do some of the umbilical canals, which at first opened free, but afterwards open into the chambers of later coils. The massive columns do not show any peculiar structure on their surface, as is the case in *Tinoporus*. The canals of the spines open into smaller ones which are arranged in rows and form longitudinal furrows on the surface of the spines by means of the chalk which the streaming protoplasm deposits near the openings of the canals.

On the dorsal side the pores of the chambers open into canals which form right angles with the surface. Between these canals the dorsal warts of chalk-substance are built. The canals into which the pores of *Calcarina Spengleri* open have already been figured by MÖBIUS [1]).

Genus **Baculogypsina** (Sacco).

This genus shows all the characteristics of the genus *Calcarina* but the chambers reach a higher development. These chambers are not only situated in a single spiral, but also secondary rows of chambers are covering the dorsal and ventral sides of the shell. The canal system is

1) MÖBIUS, K., Der Bau des Eozoon (Palaeontographica, XXV, 1879, Pl. XXXVII).

in some respects reduced, e. g. as regards the umbilical network; that of the spines is well developed. The canalsystem begins with a spiral underneath the first coils of chambers. It is possible that the genus has arisen from the fossil genus *Arnaudiella*, though the spines in that genus are not well developed. *Calcarina calcitrapoides* also shows some characteristics which may give rise to the supposition that there is some close relation with *Baculogypsina*.

Two species are met with in the Siboga-material, *B. tetraëdra* and *B. sphaerulata*.

1. *Baculogypsina tetraëdra* (Gümbel). Pl. XXIII; Pl. XXIV, figs. 1—7, 9.

Calcarina tetraëdra Gümbel, Abh. Bay. Akad. Wiss., vol. 10, 1868 (1870), p. 656, pl. 2, figs. 97*a*,*b*.
Siderolites tetraëdra Cushman, Bull. 100, U. S. Nat. Mus., vol. 1, pt. 6, 1919, pl. 44, fig. 5, pl. 45, figs. 1—5.
Siderolites tetraëdra (Gümbel), Cushman, Bull. 100, U. S. Nat. Mus., vol. 4, 1921, p. 358, pl. 75, fig. 5; pl. 76, figs. 1—5.
Baculogypsina Bonarellii et *B. Bon.* var. *tricuspidata* Osimo, Rev. Ital. di Pal., 1908, p. 40—48, Pl. II, figs. 8—20; Pl. III, figs. 1—11.

Stat. 64. Kambaragi-bay, Tanah Djampeah; up to 32 m.; abundant.
Stat. 65. 7° 0′ S., 120° 34′.5 E., depth 510 m.; a single specimen.
Stat. 164. 1° 42′.5 S., 130° 47′.5 E., depth 32 m.; 2 specimens.
Stat. 301. 10° 38′ S., 123° 25′.2 E., depth 22 m.; 9 specimens.
Stat. 310. 8° 30′ S., 119° 7′.5 E., depth 73 m.; 1 specimen.

Brief characteristics of the species.

Forma A_1. Individuals perhaps possessing the smaller megalosphere; later chambers in radiating rows, with big columns. Ends of the spines free.

Forma B. Individuals with more than three spines, situated in a single plane, and projecting with their ends free, not quite covered with chambers. First chambers forming a narrow spiral; later chambers situated in radiating rows. Columns well developed.

Forma A_2. Individuals perhaps possessing the larger megalospheric first chamber followed by a rotalide spiral. Later chambers heaped irregularly, never forming radiating rows; spines well developed and hidden even at their tops by the chambers. No columns are formed.

It is this species which was described by Cushman, 1921, and in 1919 he says on the same material (p. 366): "However, a study of the material from Maestricht shows that *Siderolites calcitrapoides* is the same generically as the species figured. Sections of the fossil material also show that the characteristics of the two are very similar"; and (p. 367): "Gümbel in 1862 describes *Calcarina tetraëdra* from the Eocene and this is used as a synonym of *Baculogypsina sphaerulata* by various authors. However, a reference to his figure shows the close relation between this and our species on plate 45, figs. 1—5. A study of the fossil material of *Siderolites calcitrapoides* shows that the fossil species and the recent one from the Philippines are apparently generically the same. They represent different species, however, and probably our recent Philippine species is the same, or very close, to that described by Gümbel from the Eocene".

The genus *Siderolites* Lamarck has been described by CUSHMAN as follows: "Test with rotaliform young, hispid, later irregular with numerous large chambers, coarsely punctuate, usually three or four blunt spines, hispid in the young, reticulations not distinct".

With respect to the species *B. tetraëdra* this description is a very good one, but as to the species of Maestricht I have a quite different opinion. I studied hundreds of specimens of the latter, and collected thousands of them myself; but never did I find the irregularly heaped chambers which are so characteristic of *Baculogypsina tetraëdra*. On the contrary, I came to the conclusion, that "*Siderolites*" *calcitrapoides* Lamarck represents a real species of the genus *Calcarina*, the chambers being only arranged in spirals; but these chambers have the shape of those of *Amphistegina*, and it is therefore that slides give easily rise to the idea that the chambers are heaped up irregularly.

Yet I can underline CUSHMAN's words when he says (1921, p. 358): "In its development *Siderolites* stands between *Calcarina* and *Baculogypsina* (= *S. sphaerulatus*, Ref.) and geologically also its first occurence is between the two as far as is known", when we add, that "*Siderolites*" = *B. tetraëdra*. OSIMO [1]) describes the forms of *B. tetraëdra* as *B. Bonarellii* and *B. Bonarellii* var. *tricuspidata*; they do not differ in any characteristic from the typical *B. tetraëdra*. They have also been mentioned by PROVALE [2]).

Three types have been found in the Siboga-material, two of which pass into each other by intermediate forms; the third is always easy to distinguish.

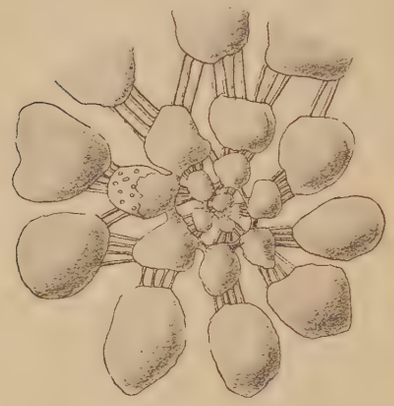
The study of this species gave me a nice example of trimorphism of the Foraminifera. Firstly I found megalospheric forms with three or four spines (Pl. XXIII, fig. 3) and very distinct columns between the chambers on the surface; secondly I studied a type without columns, also having a megalosphere (Pl. XXIII, fig. 1). Then I had already found the trimorphism of *Baculogypsina sphaerulata*, and in connection with what I had seen there, I concluded that an individual of *Baculogypsina tetraëdra*, possessing five or six spines, which were placed irregularly and somewhat in the same plane (none of them formed right angles with the plane of the initial spiral), and having clear columns, would be a microspherical specimen (Pl. XXIII, fig. 2). A slide through the centre of this individual showed that I was right (Pl. XXIII, fig. 9). Typical megalospheric forms have four spines, as is the case in *Tinoporus baculatus*, but in most cases, just as in older individuals, the spine which forms the top of the tetrad, does not develop and the shell becomes triangular. Young specimens are very much like young *Baculogypsina sphaerulata* and have already been described by CUSHMAN; the spines are covered with fine projections which are formed round the openings of the pores of the canals running through the spines (Pl. XXIII, fig. 4). The columns between the chambers are massive and provided with a canalsystem. I met with two younger microspheric individuals only, so I cannot say whether the microspheric generation grows larger than the megalospheric or not.

The microsphere (± 25 μ diameter) is followed by four coils of high and somewhat pointed chambers, as is the case in *Calcarina hispida* (Pl. XXIII, fig. 9); afterwards irregular heaps of chambers are built between the spines and the first spiral. The first coils have no thick walls, as in *Baculogypsina sphaerulata*.

1) OSIMO, G., Di alcuni Foram. dell' Eocene superiore di Celebes (Revista Ital. di Paleontologia, Anno 14, 1908).
2) PROVALE, I., Di alcuni Nummulitine e Orbitoidini dell' isola di Borneo (Revista Ital. Paleontografica, 1908—1909).

The megalosphere is a typical, large, round chamber, followed by two rotalide coils of chambers (Pl. XXIII, fig. 7), succeeded by the irregular heaps. Here, too, the first chambers are high, have somewhat thicker walls, but not at all in the same way as in *Baculogypsina sphaerulata*; all forms not only possess little spines on the surface of the pillars, but also among the pores of the chambers (Pl. XXIII, fig. 5).

The canalsystem is very characteristic. I could study the system in megalospheric forms only. The individuals show a dorsal side which is more convex than the ventral one. The pillars, however, often project to the dorsal side and so the typical conical form is not so very distinct as in *Rotalia* and *Calcarina*. The ventral side of the first coils is at its umbilicus filled up with a chalk-mass through which canals pierce in all directions; they run to the periphery and anastomose there (Pl. XXIV, fig. 4, middle). The pores of the first coils of chambers open into these canals as is the case in *Calcarina Spengleri*. Offshoots of the first canals in young specimens open on the ventral surface, as they do in *Calcarina* and *Rotalia*, but in older individuals they end in the chambers which overgrow this surface. In this way one does not see anything of the canalsystem when studying the ventral surface of an older shell. On the dorsal side the pores of the first coils end directly outward, but later on they form the communication between these chambers and the next layer. Here and there, specially on the ventral side of the shell, new canals are formed, built by outgrowths of the chambers. These canals will be met with in a primitive form in *Calcarina*; here they are formed by wartlike projections on the dorsal side. So it is obvious that the irregular chambers of *Baculogypsina tetraëdra* arise from the short canals like those which are found on the dorsal side in *Calcarina*, and then their irregular arrangement finds its explanation. In the megalospheric form which possesses columns of massive chalk-substance between the chambers, so that the latter are obliged to grow in rows radiating from the middle of the shell, these columns are formed in the same way as the warts in *Calcarina*; the spaces between them are filled up by walls and thus form the chambers. It is clear that *Baculogypsina tetraëdra* is only a higher form of *Calcarina* and directly descends from it. The canals of the spines arise directly from the ventral canalsystem. These canals have already been very accurately figured by MÖBIUS [1]) under the name of "*Tinoporus baculatus*"; even the first spiral canal round the first chamber has been figured. In such cases, in which four pillars are formed, the fourth of them communicates with the ventral system by means of canals running between the chambers of the first coils towards the dorsal side of the spiral (see fig. 4, Pl. XXIV). So dorsal spines arise not in quite the same manner as lateral ones.



Textfig 7.
Baculogypsina tetraëdra.
Central part of microspheric individual.

Textfig. 8.
Baculogypsina tetraëdra.
Chambers with spinal canalsysten.

1) MÖBIUS, K., Der Bau des Eozoon (Palaeontographica, XXV, 1879, Pl. XXXVIII).

2. *Baculogypsina sphaerulata* (Parker et Jones). Pl. XXIV, figs. 1, 8, 10—15; Pl. XXV.

Orbitolina sphaerulata Parker and Jones, Ann. and Mag. Nat. Hist., ser. 3, vol. 6, 1860, p. 33, n° 8.
Baculogypsina sphaerulata Cushman, Bull. 100, U. S. Nat. Mus., vol. 4, 1900, p. 359, pl. 75, fig. 6; Samoan Foraminifera, p. 44, pl. 15, figs. 1—3.
Tinoporus baculatus H. B. Brady (not Montfort), Rep. Voy. Challenger, Zool., vol. 9, 1884, p. 716, pl. 101, figs. 4—7.
Tinoporus baculatus Montfort, sp., R. L. Sherlock, (Bull. Mus. Comp. Zool., vol. 38, 1903, p. 357, fig. 8).

Stat. 51. Madura-bay and other localities in the southern part of Molo-strait, from 69—91 m.; 3 specimens.
Stat. 157. In Du-roa-strait, Kei-islands, 45 m.; 1 specimen.
Stat. 220. Anchorage off Pasir Pandjang, west coast of Binongka; 278 m.; 27 specimens.
Stat. 226. 5° 26′.7 S., 127° 36′.5 E., 1595 m.; 1 specimen.
Stat. 251. 5° 28′.4 S., 132° 0′.2 E., 204 m.; 1 specimen.
Stat. 252. West-side of Taam-island, 9—36 m.; 22 specimens.
Stat. 282. 8° 25′.2 S., 127° 18′.4 E., 27—54 m.; 10 specimens.

As Cushman pointed out, Sacco proposed to introduce the genus *Baculogypsina* in 1893 on account of the vagueness of Montfort's description of *Tinoporus*. The species has in most cases been confused with *Tinoporus baculatus* as is the case in Brady's description as well as in that of Sherlock. The latter gives only a photo of a slide (fig. 8). It is a slide taken from a megalospheric individual, showing four pillars, one of which is entirely visible, the other three show only their bases. The angle formed by the chamberrows and the axis of the pillars measures 40°, which angle is not characteristic of the megalospheric form of *Tinoporus baculatus* and the megalosphere is too large for it. The chambers are more irregularly arranged than is the case in *Tinoporus*.

Three types are met with in the Siboga-material, and they are distinguishable even on the outside.

Description of the three forms:

Forma A_1. On the surface regularly placed little columns of shell-substance are visible; it is therefore that on a slide right through the centre of the individual the chambers are arranged in rows as is the case in *Tinoporus* (Pl. XXIV, fig. 10; Pl. XXV, fig. 5), and these chambers only differ from those of *Tinoporus* in having smaller pores; the foramina are quite the same. The pillars are not always arranged in the same plane and their surface is not over their whole length covered with layers of chambers, but lengthwise grooved by furrows, specially in young specimens (Pl. XXIV, fig. 15; Pl. XXV, figs. 3 and 4).

Forma B. No columns are visible on the surface. This is the most primitive type and from a systematical point of view the most interesting. The chambers are not arranged in rows but irregularly heaped one upon the other (Pl. XXV, fig. 8). It therefore very much resembles *B. tetraëdra*. The chambers are flattened. The pillars are covered at their bases with chambers, and thus do not project so abruptly

as is the case in forma A_1; mostly they stand on the same level (Pl. XXV, fig. 2).

Forma A_2. Microspheric form. Only one type (Pl. XXV, fig. 6). Stoutly built columns, but placed irregularly. Pillars covered with irregularly arranged, bloated chambers. These pillars are not placed on the same level and are often irregularly shaped and bifurcated. The chambers are a little larger (Pl. XXV, fig. 8).

Both microspheric and megalospheric forms possess a rotalide embryonic apparatus, as is the case in *Baculogypsina*.

The megalospheric initial apparatus commences with a large megalosphere which, together with the two following windings of the apparatus, is separated from the other chambers by a thick wall, perforated with large pores (Pl. XXV, figs. 9 and 10), which is also found in microspheric individuals.

In young specimens the irregular succession of the chambers seems to be caused by the projecting spines; at first some chambers are built against the pillars (Pl. XXIV, fig. 15), and afterwards the space between two spines is filled up by other chambers. Within the spines run bifurcating canals. The branches of these canals open on the surface of the spines in rows of little tubes and together form the "furrows" of the spines. As has already been shown, the pillars are often covered with layers of irregularly placed chambers. The canals with their rows of pores do not communicate directly with the chambers of the first coils, but only with the secondary canalsystem of the shell. In this way the spines do not arise from the lengthened chambers, as is the case in some *Rotaliae*. The canals in the spines form the most important communications of the canalsystem with the outer world. In *Calcarina* the canals of the spines also arise from the system of the coil of chambers, and so we can draw the conclusion that there is a very close relation between *Calcarina* and *Baculogypsina*. The primary canalsystem (Pl. XXV, fig. 7) consists of a spiral canal on the ventral side of the embryonic apparatus, from which some branches run down to the surface under the shell, while others go to the periphery, and, as the shell grows older, to the chambers, as is the case in *Baculogypsina tetraëdra*. Together with these branches there are some which run between two adjacent chambers to the periphery and bifurcate before they reach the outer wall of the shell, while, at an older stage, they do so before reaching the older row of chambers. This bifurcation is characteristic of the genus *Rotalia* as well as of *Calcarina*. Some of these typical rotalide canals form the beginning of the canalsystem of the spines.

In megalospheric specimens the nucleus lies in the embryonic chamber or in the neighbouring chambers. A brown pigmentation is found in the wall of the first chamber of the shell.

III. Subfamily Polystomellinae.

Most authors look upon the Polystomellinae as a subfamily of the Nummulitidae. Neither the Amphisteginae nor the Polystomellinae belong to this very sharply defined family. The bilaterally symmetrical tests of these two subfamilies do not show such essential

characteristics as to put them together with the genus *Nummulites*, and the other characteristics are so very different, that there are no reasons to do so. The Polystomellinae, however, show great resemblance with the genus *Rotalia*. Most of the species of Polystomellinae show very fine pores; some of them possess a row of basal foramina in each chamberwall; the canalsystem shows a gradual development from the simple spiral-canal between the inner margin of the convolutions and the umbilical system to the highly developed interseptal system with forking canals of the real *Polystomellae*; in the higher form the chambers show some tendency to form alar prolongations, thus building a deep umbilicus filled up with secondary chalksubstance.

All these characteristics have been developed in the same way in the genus *Rotalia* and its relations (*Pulvinulina*, *Calcarina*, *Baculogypsina*): here also the pores are mostly very fine; the higher forms, such as *Rotalia schroeteriana*, show a row of foramina; the canalsystem, showing a pretty well developed umbilical spiral in *Discorbina* (= *Pulvinulina*) *polystomelloides* with some indications of an interseptal canalsystem, is developed into a highly specialised system in *Rotalia schroeteriana*; here it shows an umbilical system, with interseptal and forking canals; the only difference is formed by its double development in *Polystomella*, due to the symmetrical shape of the shell in the latter genus. In *Rotalia schroeteriana* as well as in *Calcarina calcitrapoides* and especially in *Arnaudiella*, the development of alar prolongations, even on the dorsal side of the shell, reaches a high degree.

So the only difference between the subfamily of the Polystomellinae and that of the Rotalinae is in its symmetrical or even nautiloid shape.

On the other hand there are only superficial nummulitical characteristics. Though the pores of the Nummulitidae are equally fine, their beginning with infundibular hollows in the chambers show some conformity with the structure of *Amphistegina*, not with that of *Rotalia*.

In most cases the foramina are not at all basal in *Nummulites*, and the canalsystem has a very different shape, showing a marginal cord; though two canals are running under each chamber, they have their origin in the marginal cord, and they never lie at the inner margin of the alar prolongations, but are always situated just over the marginal cord and communicate with it. From these spiral-canals a kind of interseptal canals branch off, but these canals are very irregularly shaped and show only a distant resemblance with the interseptal canals of the Rotalinae.

Though it is very probable that the Rotaliidae and the Nummulitidae are descended from the same kind of ancestors, it will be better to look upon them as different families. The Polystomellinae therefore must be separated from the Nummulitidae and classed with the family of the Rotaliidae.

I cannot say whether the genus *Faujasina* d'Orbigny belongs to the group of *Polystomella*, though the shell shows the structure of *Truncatulina* and possesses only a single aperture. A new study especially dealing with its inner structure can only solve this question.

Genus **Polystomella** Lamarck.

Characteristics those of the subfamily.

The species, which have been described hitherto by different authors, possibly belong to three or four series of forms, or to three or four, somewhat varying, species.

1. *Polystomella striato-punctata* (Fichtel et Moll). Pl. XXVI, figs. 3, 4, 7; Pl. XXVII, figs. 9 and 10; Pl. XXVIII, fig. 9.

Nautilus striato-punctatus Fichtel et Moll, 1798, Testacea Microscopica etc., p. 61, pl. IX, figs. *a, b, c.*
Polystomella striato-punctata Parker et Jones, 1859, Ann. Mag. Nat. Hist., n° 1, ser. 3, vol. III, p. 103, n° 6; BRADY, 1884, Challenger Reports, p. 733, pl. CIX, figs. 22, 23; EGGER, 1893, Abh. Kgl. bayr. Akad. d. Wiss., München, II. Cl., vol. XVIII, pt. 2, p. 433, pl. XIX, figs. 49, 50; HERON-ALLEN and EARLAND, 1909, Journ. Roy Micr. Soc., p. 695; CUSHMAN, 1914, U. S. Nat. Mus., Bull. 71, pt. IV, p. 31, pl. 18, fig. 8 (here the other literature); HERON-ALLEN and EARLAND, 1915, Trans. Zool. Soc., London, vol. XX, pt. II, p. 732.
Polystomella striato-punctata var. *selseyensis* Heron-Allen et Earland, Journ. Roy. Micr. Soc., 1909, p. 695, pl. XXI, fig. 2.

Stat. 49. 8° 20'.5 S., 119° 4'.5 E., 369 m.
Stat. 77. 3° 27' S., 117° 36' E., 59 m.
Stat. 260. 5° 36'.5 S., 132° 55'.2 E., 90 m.

This species, though one of the most widely distributed recent Foraminifera, occurs very rarely in the samples of the "Siboga". It is however quite possible, that it would have been collected more frequently, if most of the bottomsamples had not been thrown away, for in some samples of the cableships "Telegraaf" and "v. Gogh", S. W. of Sumatra, it occurs in rather large quantities, and MILLET [1]) also refers to it. Most of the material I studied I got from dredgings in the North-Sea near Texel (Holland).

Yet this species is of some importance as it has never been studied with respect to its internal structure and as it shows the simplest development in the *Polystomella*-series.

Only megalospheric specimens could be studied. The number of chambers in the last convolution amounts to 14 (Pl. XXVII, figs. 9, 10); these chambers are rather more high than broad, and with their alar prolongations they do not reach the centre of the shell, but they form an umbilicus filled up with coarse buds of chalk-substance, through which short umbilical canals run outwards. These canals (Pl. XXV, figs. 3, 4) are connected with a well developed spiral canal on either side of the shell, from which the meridional interseptal canals branch off at a short distance from the periphery of the shell. From them arise the "forking" canals which, however, do not fork and possess rectangular mouths at the chamber sutures, while the walls of these openings are coarsely punctuated (Pl. XXVI, fig. 7). These walls are separated by bridges of chalk, under which the retral processes of the chambers are visible (Pl. XXVI, fig. 4). The chambers themselves communicate with each other by means of a row of about 5 or 7 round foramina at their base (Pl. XXVIII, fig. 9). The "forking" canals of a preceding convolution open into the chambers of the next. In young individuals it is clearly visible that the spirals are built by the alar prolongations of the chambers, being mostly very irregularly shaped and a comparison with the canalsystem of *Nonionina asterizans* (Pl. XXVI, figs. 1 and 2) will easily show the relation between these two systems. The only difference between the genera *Nonionina* and *Polystomella* seems to be in the shape of the foramina, and even that may not be a constant difference, as is shown in *Nonionina orbicularis* Brady where a composite mouth is found. *Nonionina asterisans* also often shows three or four rounded openings instead of only one, and its canalsystem shows a very great resemblance with that of *Polystomella*,

1) MILLET, F. W., XI. Report on the Recent Foraminifera of the Malay Archipelago, collected by Mr. A. DURRAND; Part XVII, conclusion (Journ. Roy. Soc., London, Dec. 1904).

especially with that of *Polystomella striato-punctata*. There are some indications that *P. striato-punctata* and *P. crispa* are more allied with one another than really distinct species are in most cases. RHUMBLER [1]) says that: "Bei einzelnen Individuen erst der Charakter der *P. striato-punctata* bei den Kammern der Schlusswindung zum Vorschein kommt, während die vorausgehenden Schalenteile durch geringere Abrundung des peripheren Schalenrandes und deutlichere Ausgestaltung der Kammerbrücken ganz das Aussehen von *P. crispa* tragen". And MILLET [2]) has also mentioned the fact, that "Wherever there is abundance of examples the characters of these two forms become so involved that it is impossible to draw anything like a distinct line of separation between them".

2. *Polystomella crispa* (Linné). Pl. XXVI, figs. 5, 6, 8, 9; Pl. XXVII, figs. 5—8, 11 and 12; Pl. XXVIII, figs. 1, 2, 3, 5, 6, 7, 12.

Nautilus crispus Linnaeus, Syst. Nat., ed. 12, 1767, p. 1162.
Nautilus macellus Fichtel et Moll, 1798, Test. Micr., p. 66, pl. X, figs. *e—g*.
Polystomella crispa Lamarck, Anim. sans Vert., vol. 7, 1822, p. 625, n° 1; BRADY, 1884, Rep. Voy. Challenger, Zool., vol. 9, p. 736, pl. CX, figs. 6, 7; CUSHMAN, Bull. 71, U. S. Nat. Mus., pt. 4, 1914, p. 32, pl. 18, fig. 1 (here the other literature).
Polystomella macella Parker et Jones, 1859, Ann. Mag. Nat. Hist., 1860, p. 104, n° 8; BRADY, 1884, Chall. Rep., Zool., vol. 9, p. 737, pl. CX, figs. 8, 9, 11; HERON-ALLEN and EARLAND, 1909, Journ. Roy. Micr. Soc., p. 696, pl. XXI, fig. 3; CUSHMAN, 1914, U. S. Nat. Mus., Bull. 71, pt. IV, p. 33, pl. 18, fig. 3 (here other literature).

Only few specimens have been met with in the stations:

Stat. 49. 8° 20'.5 S., 119° 4'.5 E., 369 m.
Stat. 71. Makassar and surroundings, up to 32 m.
Stat. 77. 3° 27' S., 117° 36' E., 59 m.
Stat. 99. 6° 7'.5 N., 120° 26' E., 16—23 m.
Stat. 166. 2° 28'.5 S., 131° 3'.3 E., 118 m.
Stat. 260. 5° 36'.5 S., 132° 55'.2 E., 90 m.

There are three forms in this species, the first with very large pronucleus (± 90 μ), showing the characteristics of the typical *P. crispa* (Pl. XXVII, figs. 5 and 6), the second with a very minute first chamber (15 μ), being the microspheric one (Pl. XXVII, figs. 11 and 12), and the third showing the characteristics of *Polystomella macella* (Pl. XXVII, figs. 7, 8), having an initial chamber of about 60 μ.

The chambers show the typical arrangement of the true Polystomellinae; they possess however, some peculiarities. The most striking external characteristic is that the "forking" canals, which, however, never really fork, do not open with symmetrically formed mouths, but are directed towards the following chamber, thus forming smooth gullies in the walls of the chambers (Pl. XXVI, figs. 5, 6; Pl. XXVIII, figs. 1, 2). Between these gullies are the bridges, covered with minute tubercles. In this way the openings of the forked canals are unsymmetrically fan-shaped, whereas in *P. craticulata* they obtain their symmetrical habitus, which result in the forked forms in that species.

The inner structure shows the typical outgrowth of the canalsystem, intermediate in its development between that of *P. craticulata* and *P. striato-punctata* (Pl. XXVI, figs. 5, 6, 8;

1) RHUMBLER, L., Foram. v. Laysan und den Chatham-Inseln (Zool. Jahrb., vol. 24, pt. I, 1906, p. 73).
2) MILLET, 1904, l. c., p. 603.

Pl. XXVIII, figs. 3, 7, 12). The alar prolongations are very well developed and the transverse section of the chambers in the megalospheric typical form and in the microspheric one has a triangular shape; thus the shell possesses a sharp "keel". The form named *P. macella* lacks this "keel"; another peculiarity of this form is, that the foramina are not ranged in a single V-shaped line at the base of each chamber, but in the older convolutions are often scattered over the whole wall (Pl. XXVI, fig. 6). The umbilical chalk-mass is much more developed in the typical forms than in *P. macella*; this development is due to the fact that the chambers are much broader in the typical forms.

3. *Polystomella craticulata* Fichtel et Moll. Pl. XXVI, figs. 10—15; Pl. XVII, figs. 1—4; Pl. XXVIII, figs. 4, 8, 10, 11.

Nautilus craticulatus Fichtel et Moll, Test. Micr. 1803, p. 51, pl. 5, figs. *h—k*.
Polystomella craticulata d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 284, n° 3; BRADY, 1884, Rep. Voy. Challenger, Zool., vol. 9, p. 739, pl. 110, figs. 16, 17; CUSHMAN, Bull. 71, U. S. Nat. Mus., pt. 4, 1914, p. 34, pl. 13, fig. 4.

Stat. 49. 8° 20'.5 S., 119° 4'.5 E., 369 m.
Stat. 77. 3° 27' S., 117° 36' E., 59 m.
Stat. 133. Anchorage off Lirung, Salibabu-island. Up to 36 m.
Stat. 164. 1° 42'.5 S., 130° 47'.5 E., 32 m.
Stat. 260. 5° 36'.5 S., 132° 55°.2 E., 90 m.
East coast of Borneo, near Balik-Papan (Dr. SCHÜRMANN, 1925).

Though the material in all stations was very rare, I was glad to be able to make a detailed study of the inner structure of the shell, as this highly developed species of *Polystomella*-series is of much interest with respect to the canalsystem.

Yet, there is not much reason to give a detailed description of the inner structure of *Polystomella*, as many authors already have given a minute exposure of it. So my investigations have not thrown more light on this structure and a brief account of their results, together with the figures, will suffice.

Microspheric individuals have a somewhat larger size than megalospheric ones; they possess in their last coil about 28 chambers and between these chambers two rows of canal-pores are visible (Pl. XXVI, figs. 10, 13 and 15; Pl. XXVII, figs. 1 and 2). The umbilical bud of secondary chalk-mass is a little narrower than is the case in megalospheric forms, so that the total length of the alar prolongations of the chambers in greater.

Each chamber shows on its backside near the periphery a row of short, triangular retral processes, each of which is situated just between two forked canals. The canalsystem in microspheric forms is similar to that in megalospheric specimens (Pl. XXVIII, fig. 8). It begins with two spiral coils on the dorsal and ventral sides of the embryonic apparatus. These two spiral canals (Pl. XXVIII, fig. 10) run internally to the lateral ends of the alar prolongations of the chambers and are rather compressed in the direction of the axis of the shell, so that in a section they look oval. From these spirals canals run directly to the periphery of the shell right through the hyaline chalk-mass of the navel (Pl. XXVII, fig. 11; Pl. XXVIII, fig. 8). These canals hardly ever bifurcate and so the pores, seen on the outside of the shell in the umbilical region, are distributed at equal intervals in the form of a spiral. The two spirals are connected

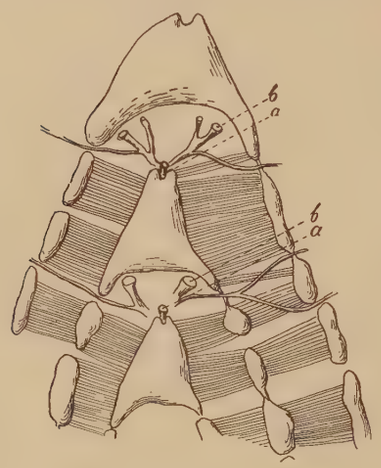
by the meridional canals running between the septa of two following chambers. These canals show that they are typical interseptal spaces; they are very narrow, when seen in a horizontal section, but very high, nearly as high as the chambers between which they run, when seen in a transverse section. These meridional canals form little, short canals directed to the periphery: the "forking canals", which bifurcate before reaching the periphery just at the suture between two chambers, and then run between two retral processes of the chambers, as mentioned above. These short forking-canals, at first opening on the surface of the shell, will open into the lumina of the chambers of the following convolution, when these chambers have grown over this surface. This very connection of the interseptal canalsystem and the chambers in those cases, in which alar prolongations overlap the foregoing convolutions, shows that this system cannot be identified with the marginal-cord-system in the NUMMILITIDAE There is, however, another important difference between the above-described system of *Polystomella* and its relations, the ROTALIDAE, and that of the NUMMULITIDAE. When we describe the canalsystem of the latter group of highly-specialised Foraminifera, we shall see, that at the peripheral margin of each chamber a canal is built at the very moment when the chamber itself is formed; this canal is partly sunk in the lumen of the chamber and, together with its branches, forms the marginal cord. So we never find the spiral-canals at the outer corner of the alar prolongations, as is the case in *Polystomella* and besides the last convolution of *Nummulites* and its relations possesses the marginal cord at its outer margin, whereas at the outer margin of *Polystomella* no canalsystem will be found. This is a very important difference. For, when we imagine, how the canalsystem in the two different sub-families may be formed, we find that in the POLYSTOMELLIDAE the spiral-canals, which have been compared by CARPENTER with the "two" marginal canals of the NUMMULITIDAE must be formed by the following row of chambers, leaving some space between their inner wall and the wall of the former convolution, whereas in the NUMMULITIDAE the canals of the marginal cord are formed within the walls of the chambers themselves and in the outer walls too. Only the system, that forms the interseptal canals in the NUMMULITIDAE may in some way be compared with the canalsystem of the POLYSTOMELLIDAE. The system of the latter, however, must be identified with that of the ROTALIDAE, from which it only differs in having a double spiral, which is a consequence of the symmetrical structure of the shell.

In most shells, both micro- and megalospheric, I found that the very fine and numerous pores, piercing the walls of the chambers, often open into the forking canals; this is another difference with the marginal cord of *Nummulites*, in which genus they never communicate with that canalsystem. The megalospheric forms, with their very large proloculum (about 160 μ), also show about 28 chambers in their last convolution, but the total number of convolutions and chambers is much smaller. The canalsystem has a firmer structure, the spiral-canals form flattened spaces and the "forking" canals do not really bifurcate but form a somewhat fanshaped opening, so that the sutures between two following chambers show rows of "furrows that pass transversely between the septa" [1]). Intermediate structures between the well developed forked canals and the fanshaped ones may also be found. It is possible that the megalospheric forms with typical forking canals have the smallest proloculum, but I have not material enough to state this trimorphy.

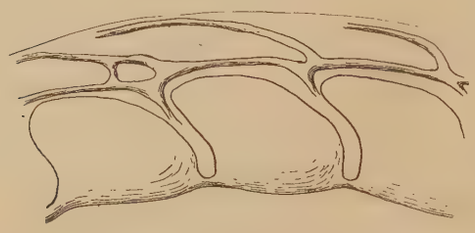
1) CARPENTER, W., Introduction etc. (1862, p. 280).

Family NUMMULITIDAE.

This family can be distinguished very clearly from the family of the ROTALIDAE, when we consider the canalsystem. In the ROTALIDAE this system consists only of two kinds of canals, the umbilical spiral canal (or canals) and its outgrowths, and the interseptal system. They are formed by spaces left between the successive chamberwalls and that is why they are often shaped rather irregularly, especially in the higher forms. In the NUMMULITIDAE on the other hand these two systems of canals (or interseptal spaces) are formed in the same way, but moreover there exists a third system, forming the "marginal cord". This system is originally formed by a single canal, running at the outer margin of the chamber-convolutions; so it is not a space, left between walls, but it has been formed by a single chamberwall (textfigure 9). The chambers form a hollow notch at their outer margin, in which the canal runs. The canalsystem of *Nummulites* has been very well described by CARTER [1]), when he deals with *N. Ramondi*. He describes the marginal cord-canal as "interseptal canal" sending off two branches to communicate with the great canals respectively, while these great spiral canals are those mentioned by CARPENTER. The cavity in the chambers, in which the marginal canal runs, has been figured also. In later convolutions the marginal cord is branched and communicates with the spiral system and the interseptal canals. An other difference is, that in the ROTALIDAE the spiral system consists of a mostly irregular spiral space at the umbilical margin of the convolution of the chambers. Thus this spiral is formed by the chamberwalls on one side and the umbilical secondary chalk-mass on the other; these two structures of chalk leave between them the space, named spiral canal. In the NUMMULITIDAE, however, the spiral



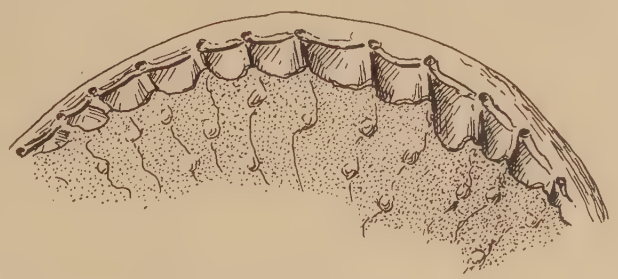
Textfigure 9. *Nummulites laevigata.*
Transverse section of canadabalsam-preparation.
a. marginal cord. *b.* "spiral" canal.



Textfigure 10. *Nummulites laevigata.*
Part of convolution, with interseptal and spiral canals.

1) CARTER, H. J., On the fossil Foraminifera of Scinde (Ann. Mag. Nat. Hist., Ser. 3, vol. 8, 1861, p. 470, Pl. XVII, fig. 15).

system of canals does not run at the umbilical margin of the chambers, but at their peripheral one (textfigure 10), thus joining the marginal cord. Even if the chambers of later convolutions overlap those of earlier ones, the place of the spiral system is not changed; this is always the case in the ROTALIDAE. There is another peculiar difference between the so-called spiral canals of the NUMMULITIDAE and the true spirals of the ROTALIDAE. In NUMMULITIDAE, as I will mention in detail when dealing with *Operculina*, two canals run from the marginal cord over each chamber and form the interseptal canals of the next chamber of the following row. In this way the "spiral" canal really consists of these successive short canals, running parallel to the marginal cord but having no communication with each other (textfigure 11). In transverse sections they seem to form a continuous canal, but by canadabalsam-preparations taken from *Operculina* and from *Nummilites laevigata* one can easily be convinced of the truth: a real spiral-canal-system does not occur in NUMMULITIDAE. The marginal cord replaces it.



Textfigure 11. *Nummulites laevogata.*
Margin of an individual, from which the outer parts have been removed.

In connection with this clear definition of the family, distinguished by its marginal cord, it will be obvious that some genera, considered by other authors as real NUMMULITIDAE, must be removed from this family. If we only consult the most recent authors such as CHAPMAN (1902) and CUSHMAN (1925), who wrote about the classification of Foraminifera, we must remove from the NUMMULITIDAE the following genera: *Schwagerina*, *Fusulina*, *Nonionina*, *Polystomella*, *Archaediscus*, *Amphistegina*, *Orbitoides*, *Orthophragmina*, *Lepidocyclina*, *Myogypsina*.

Cycloclypeus, though lacking a marginal cord in megalospheric individuals, must be considered as a true *Nummulites*, as the whole organisation, except the spiral arrangement of the chambers, is that of *Heterostegina* and, moreover, it is linked to this genus by *Spiroclypeus*, a fossil genus.

There is a slight possibility that genera such as *Amphistegina* and *Fusulina* really belong to the family of NUMMULITIDAE; but I do not believe that *Amphistegina* ever possessed a canalsystem, as its most ancient forms, such as *A. Fleuriausi*, did not possess such a system; it is possible, that *Amphistegina* forms an ancestral type of *Nummulites*, as real *Nummulites* have never been formed in older eras than those in which the first Amphisteginae occur (Carboniferous) (*Nummulites pristinus* Brady, described from carboniferous beds of Namur, really must be looked upon as *N. variolaris* from the Eocene). This is the place to point out that in literature more than once the opinion will be met with that some older *Nummulites* exist without a trace of a canalsystem. GÜMBEL e. g. described such a form from the Upper-carboniferous of Dalmatia, together with *Neoschwagerina*. The only difference between this "*Nummulites*" and a real *Amphistegina* consists in the lack of the edge in the alar prolongations of the chambers. As I pointed out in my paper on *Amphistegina Fleuriausi*, this characteristic is not of any generic value in *Amphistegina*. This is in contradiction with the statement of DOUVILLÉ (1906, p. 592: "Les préparations de ces *Nummulites* en lame mince, que nous avons pu examiner, montrent bien en effet l'existence de canaux soit dans les cloisons, soit dans la

carène, mais leur irrégularité et leur disposition en zigzags semblent bien indiquer qu'il ne s'agit là pas de véritables canaux analogues à ceux des *Operculines*", so that we shall have to point out that we must consider a Foraminiferum a true *Nummulites* only when a clear canalsystem with marginal cord can be found. In all other cases we are not entitled to give the name of *Nummulites* to a species. As this point has been neglected by several authors, a revision of the fossil forms of NUMMULITIDAE can only give some certainty about it. I believe that many so-called *Nummulites* really are species of *Amphistegina* (this is also the case in the genus *Nummulostegina* Schubert from the Upper-carboniferous).

As, however, not one conclusive argument can be found for the supposition that *Amphistegina* is a true *Nummulites*, the genus *Amphistegina* cannot be included in this family. As I already showed, the genera *Nonionina* and *Polystomella* belong to the ROTALIDAE. Not much is known about *Archaediscus*, but as there are no true chambers in the shell of that genus, it is rather improbable that it would be even an ancestor of the NUMMULITIDAE, as GÜMBEL already suggested (1872).

The genera allied to *Orbitoides* belong to the family of TINOPORIDAE, as I have already pointed out.

As the only true NUMMULITIDAE must be looked upon:

Operculina (and *Operculinella*).
Nummulites (and *Assilina*, *Paronaea*).
Heterostegina.
Heteroclypeus.
Cycloclypeus.
Spiroclypeus.

It is possible that the genus *Nummulites* in its primitive species, like *Assilina*, forms the ancestral form of all other groups, including *Operculina*.

The very close alliance between the forms of this group also appears in the remarkable coincidence in the habitus of the three forms constituting each species.

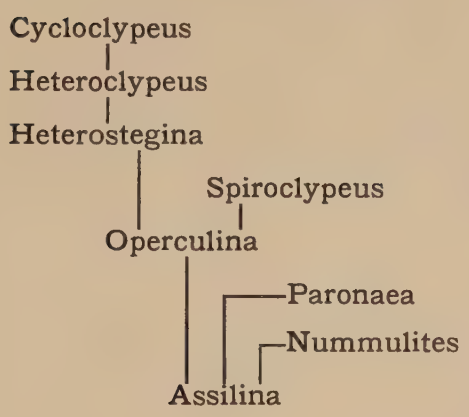
The A_1-form, megalospheric with relatively small proloculum, always shows a lack of secondary chalk material in the neighbourhood of the sutures and of the walls. The walls in these forms are thin and smooth.

The B-form, the microspheric one, is always much larger and often shows secondary chalk, gathered only in the centre of the shell, whereas the outer part forms a very thin but broad flange.

The A_2-form is built more solidly, with well developed secondary shell material throughout, and thicker walls. The chambers have a more round shape.

Especially all fossil material must be revised with respect to these points; I am sure that it will appear that different "species" from the same localities in reality belong to the same species. Possibly three or four forms belonging to the same species have been described in this way, as the intermediate forms between A_2 and A_1 are equally distinguished as separate species.

Scheme of Relations:



1. *Operculina complanata* (Defrance). Pl. XXXI; Pl. XXII, figs. 2—9; Pl. XXXIII.

Operculina venosa Fichtel et Moll, 1798, Test. Micr., p. 59, pl. 8, figs. *e—l.*
Lenticulites complanata Defrance, 1822, Dict. Sci. Nat., vol. XXV, p. 453.
Operculina complanata d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 281, pl. XIV, figs. 7—10; Modèle n° 80.
Operculina gaimairdi d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p, 281, n° 5.
Operculina discoidalis d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 296, n° 1.
Operculina granulosa Leymerie, 1846, Mém. Soc. Géol. France, ser. 2, vol. 1, p. 359, pl. 13, figs. 12*a, b.*
Amphistegina cumingii Carpenter, 1859, Phil. Trans. p. 32, pl. 5, figs. 13—17.
Nummulites cumingii Brady, 1884, Chall. Rep., Zool., vol. 9, p. 749, pl. 112, figs. 11—13.
Operculina complanata var. *granulosa* Brady, 1884, Chall. Rep., vol. 9, p. 743—744, Pl. CXII, figs. 6, 7, 9, 10.
Nummulites venosa Chapman, 1895, Proc. Zool. Soc., London, p. 47.
Operculina bartschi Cushman, 1921, U. S. Nat. Mus., Bull. 100, vol. 4, p. 37*b*, fig. 13.
Operculina bartschi var. *plana* Cushman, 1921, ibidem, p. 378—379, pl. 74, figs. 2*a, b.*
Operculina discoidalis var. *involuta* Cushman, 1921, ibidem, p. 380, fig. 16.
Operculina elegans Cushman, 1921, ibidem, p. 381, pl. 97, fig. 3.

Numerous specimens have been found in the Siboga-material at the following stations:

Stat. 64. Kambaragi-bay, Tanah Djampeah; very abundant, covering the bottom with a layer of shells; up to 32 m.
Stat. 104. Sulu-harbour, Sulu-island; 13 m.; ± 20 specimens.
Stat. 133. Anchorage off Lirung, Salibabu-island, up to 36 m.; 14 specimens.
Stat. 204. 4° 20′ S., 122° 58′ E., 75—94 m.; 4 specimens.
Stat. 226. 5° 26′.7 S., 127° 36′.5 E., 1595 m.; 3 specimens (habitus of *O. ammonoides*).
Stat. 262. 5° 53′.8 S., 132° 48′.8 E., 560 m.; 2 specimens.
Kwandang-bay; 360 m.; leg. NOUHUYS, 1914, 15 specimens, some of which have the habitus of *O. ammonoides.*
Balik-Papan-bay, leg. Dr. SCHÜRMANN, 1925; abundant.

Resumed characteristics of *Operculina complanata.*

Forma A_1. Sutures never with well developed buds of secondary chalk (only the central part of the shell shows some heaps of clear chalk-

material), and very little chalk buds on the chamberwalls. Proloculum about 35 μ; marginal cord not very distinguishable in the more involute specimens. Chambers very numerous, especially in flat individuals.

Forma B. Always very large specimens (up to 9 mm. diameter) with smooth walls, ornamented with very small chalk buds. Only the centre of the shell with chalk masses on the sutures. Chambers very numerous. Proloculum 27 μ.

Forma A_2. Sutures with very well developed buds of secondary chalk and with very large masses of chalk-material on the walls. Most individuals are very strongly built, with somewhat rounded chambers, the number of which is mostly a little smaller. Proloculum about 60 μ.

The species *Operculina complanata* shows a very high degree of variability which in most cases seems to be due to trimorphism and in others to outward circumstances, viz. the quantity of chalk and the depth of the water. Some authors, especially CUSHMAN, have planned even ten species and varieties on account of some differences which are often so very insignificant, that one is always in doubt, whether a specimen belongs to one species or to the other. No sound reasons have been put forward by CUSHMAN; I think that CUSHMAN's Philippine collection showed no typical form, as has been figured by D'ORBIGNY, but I do not know why polymorphism and other variations should not be allowed to this species. Even the fact, that CUSHMAN studied each station separately, cannot be taken as a reason to divide the material into different species, as he did. As to *Operculina* the Siboga-material shows some difference between the populations of different stations. Yet the fact that CUSHMAN's "species" often occur in localities in which other forms are also met with, does not make one a supporter of his views. In one station, 64, where thousands of specimens were gathered, most of CUSHMAN's species and varieties were mingled together, with intermediate forms between them.

The typical nummulitic canalsystem together with the simple development of the whole organism, have given rise to the opinion that *Operculina* should be the most primitive of all NUMMULITIDAE. Yet it is very remarkable that, geologically, *Operculina* is much younger than *Nummulites*, which occurs even in the palaeozoic age. So it is possible, that *Operculina* forms a younger branch of the NUMMULITIDAE, originating from a simple *Nummulites* with undivided chambers possessing alar prolongations; it seems to be a young Nummulite showing paedogenesis; only the first coils of chambers of the adult *Nummulites* are met with in *Operculina*. CARPENTER [1]) says: "The difference between *Operculina* and *Nummulina* comes to rest only on the general form of the spire and the conspicuousness of its convolutions, characters which seem by no means sufficient for the separation of the former as a genus distinct from the latter".

It is obvious that such an organism, possessing all possibilities of the higher *Nummulites* in its genotype, will show a great variation with regard to its phaenotype; besides, it is by no means improbable that this organism has given rise to forms such as *Heterostegina* and

1) CARPENTER, W., 1862, l. c., p. 248.

Cycloclypeus. In this light we must consider the words of LISTER [1]): "while *Operculina* is closely connected on the one hand with *Nummulites*, it forms, on the other, the simplest term of a series — *Operculina*, *Heterostegina*, *Cycloclypeus*".

As the most typical form of *O. complanata* I will mention the microspheric form which has the characteristics of *O. bartschi* Cushman. The coils are rapidly widening and some of the individuals have a diameter up to 9 mm. The central portion is biconvex and composed of several coils of chambers, the first of which is a microsphere of about 27 μ, followed by a very minute second chamber, just as LISTER described it (1903, fig. 55, p. 127). The chambers of the last coils are narrow and numerous, and the sutures are not ornamented with secondary chalk-substance. This substance, however, is represented by little protuberances on the walls of the chambers and by larger granulations in the centre of the shell. Little heaps of clear shell-substance on the outer walls were first described and figured by CARPENTER (1862, fig. 12, Pl. XVII); the pores disperse on the spot where a heap of shell-substance arises and there is therefore no doubt that the pores and the heaps have something to do with one another. These granulations show fine layers of clear chalk and these layers are also seen, but not so clearly, in the other parts of the shell. So we see that these granulations are due to a greater production of chalk on some parts of the shell, and as the pores always have the inclination to reach the surface vertically, they disperse. Sometimes, probably when the specimen lived in chalky water, granules also appear in microspheric tests above the sutures, near the openings of the canalsystem.

Megalospheric specimens belong to two types; one of them has a large proloculum measuring about 60 μ; in normal conditions they show a very large secondary skeleton, with large buds of chalk at the sutures, sometimes melting together into rows; they also possess granulations in radial rows on the chamberwalls. These granulations often melt together into longer hills, directed vertically to the sutures between the chambers. In such cases these hills are situated exactly between the foramina connecting two chambers, thus showing that the formation of secondary chalk-masses is due to the streams of chalky protoplasm [2]). This type with large proloculum forms the species *O. granulosa* Leymerie [probably in water, deficient in chalk, the granulation is only confined to the openings of the canalsystem (*O. bartschi* var. *ornata* Cushman and *O. Philippinensis* Cushman), and finally very smooth-walled specimens appear; it is possible, that in such regions also occur the individuals with chambers showing alar prolongations in various degrees, resulting in the nummulitic type (*O. venosa* = *Nummulites cumingii* Carpenter); at least "*Nummulites cumingii*" only occurs in water near the coast].

The other type shows at the most a diameter of the initial chamber of about 35 μ, and the only structure found on the surface of the shell are small knobs scattered very regularly on the surface of the chamberwalls. The shell is very thin, smooth and translucent and only the centre often possesses a large knob of clear shell-substance (*O. bartschi* var. *plana* Cushman). These forms result in *O. gaimairdi* d'Orbigny in which the revolving suture is very distinct and projecting, while granulations often appear in the neighbourhood of the openings of the suture-

1) LISTER, J. J., 1903, l c., p. 128.

2) A very fine argument to this thesis has been given by F. DETTMER (Neues Jahrbuch f. Min., Geol. u. Paläont., Jg. 1911, Vol. I, p. 150, Taf. XII, fig. 4); having studied a regenerated specimen of *Frondicularia Cordai* Reuss the author comes to the conclusion that "die Oberflächenskulptur .... bis zuletzt von der Sarkode abhängig war".

canals. *O. Philippinensis* Cushman belongs to this group of forms. Involute specimens of this kind with chambers more or less swollen up, form *O. discoidalis* and *O. discoidalis* var. *plana* Cushman and they often resemble *O. venosa* (Fichtel et Moll).

It is possible that *O. ammonoides* (Gronovius) only represents a deep-water-form of *O. complanata*. An exhaustive discussion is to be found in one of the works of HERON-ALLEN and EARLAND [1]) (*O. elegans* has not been met with in the Siboga-material).

The shape and number of the chambers and the decline of the sutures is a very variable characteristic and can never be looked upon as typical of the species. All kinds of chambers and of granulations occurred in the specimens gathered at one station, but only a single form of microspheric specimens was found there (station 64). It needs only for me to draw the attention to the beautiful work on *Peneroplis* by DREYER [2]) to show, that there is nothing particular in this variability of *O. complanata*. Only the microspheric form can be regarded as typical and more or less unvariable, as is the case in most Foraminifera.

As I have already explained in the introduction, it is not strange at all that the forms, gathered at different stations, belong to different types; yet these types, owing to different circumstances and different stages of reproduction, may belong to the same species, in the same way as the different cells in the body of a higher organism belong to the same species.

The inner structure of the shell is very peculiar and interesting, as the same structure is met with in all nummulitic species, and as the structure in higher NUMMULITIDAE may be explained by this *Operculina*-structure.

CARPENTER (1862, p. 256—260) has given such a beautiful and in most cases accurate description of the canalsystem of the shell of *Operculina*, that it would be rather superfluous to describe it once more. There are, however, in CARPENTER's description some obscure parts, and to give a clear idea of the relation between the structure of *Operculina* and that of *Heterostegina* and *Cycloclypeus*, it is unavoidable to give here once more a detailed description of this important canalsystem.

The most typical structure of this system is formed by the "marginal cord" as CARPENTER called it. It begins with a single canal in the wall between the first two chambers and the coil surrounding them; this canal can be traced between all further coils of chambers, for the walls of this canal form a furrow at the margin of each chamber, so that the canal lies beneath the marginal cord proper. Just at the base of each sutural wall two branches of the canal go in the direction of this wall and, anastomosing, form little canals at the periphery of the shell which open near the sutures on the surface and form the granulations on these sutures.

Here our views differ from those of CARPENTER, for the latter believes there are two canals running along the margin of the coils of chambers. These basal canals, which CARPENTER also describes and figures, are seen in transverse section "at each junction of the marginal cord with the tubular substance"; but they are really nothing else than the bases of the two canals which run through the sutural walls, originate in the marginal cord and cut through in section just where they turn round to reach the sutural wall (see for canalsystem Pl. XXXII, figs. 2, 4, 7, 8, 9; Pl. XXXIII, figs. 1—8 and 10). CARPENTER also figures (Pl. XVII, fig. 10) these two

1) HERON-ALLEN, E. and EARLAND, A., Clare Island Survey, pt. 64, Foraminifera (Proc. Roy. Irish. Acad., vol. XXXI, 1913, p. 148).
2) DREYER, F., Peneroplis (Eine Studie zur biologischen Morphologie und zur Speciesfrage), Leipzig, 1898.

spiral canals running along "the exterior of the first two" chambers of the shell. In reality these "two canals" in this figure are no canals at all, but the two edges of the chambers, which are a consequence of the projection of the wall of the marginal canal into the cavity of the chambers.

It seems that in the later coils one marginal canal is not sufficient to form a way for the protoplasm and therefore more canals arise from it, which build a network of canals, the "marginal cord". The meshes between these canals are filled up with prismatic chalk masses, arranged fan-like, when seen in a transverse section. These prismatic masses project a little from the surface of the margin, forming there irregular ridges and furrows, which probably grow into other canals, when a new whorl of chambers covers the margin.

Each chamber is connected with the two neighbouring chambers of the same coil by means of two kinds of foramina; one of them is placed at the base of the chamber, called "principal aperture" by CARPENTER, the others have the shape of round pores with mouths growing wider when opening into the chambers, named "secondary pores" by CARPENTER. As there might be some confusion with respect to this name and to the "pores" in the outer walls of the chambers, I will name these structures principal and secondary foramina further on. They are of enormous importance with respect to the structure of *Heterostegina* and *Cyclocly-peus*. The principal foramen in all specimens I studied had a triangular shape, as I have figured. The secondary foramina in very complanate specimens are arranged in a single row and in biconvex specimens they are placed more irregularly. This difference is of very great importance, for they give the real clew to the relations between *Nummulina* and *Heterostegina*. These secondary foramina of *Operculina*, namely, are predestinated to build the foramina of the little chambers of *Heterostegina*, as well as those of the chambers of *Nummulina*; the arrange-ment of the chambers in these genera is in this way closely connected with the arrangement of the secondary foramina of *Operculina*. As we have seen, that in this genus two kinds of arrangements of the secondary foramina are met with, we also find, that in *Nummulina* the chambers are arranged in two directions, whereas in *Heterostegina* they are situated in a single layer. Here we will look back upon our supposition that *Operculina* should be a young *Nummulina* showing paedogenesis to ripeness: we must look upon the biconvex forms with "nummulitically" arranged secondary foramina as *Nummulites* in which the formation of secondary chambers has been kept down. There are, however, some facts which cannot be understood in this light. Firstly, fossil Operculinae, viz. those from the lower Eocene, described by GÜMBEL, are of the complanate type; secondly, microspheric specimens are always very large and complanate forms, though they always show primitive characteristics in other Foraminifera. As we have shown, no differences are met with between the primary canalsystem of *Operculina* and that of *Nummulites*. As all "NUMMULITIDAE" from a period older than the Tertiary one are very small, it is quite possible, that palaeozoic and probably also mesozoic *Nummulites* are real Operculinae. In this case the Operculinae are the descendants of the fore-fathers of the NUMMULITIDAE, as well as of those of the HETEROSTEGINIDAE. Only a new revision of the older species of *Nummulites* may solve this problem.

It is here the place to give some remarks on the function of the secondary canalsystem. When observing a living specimen of *Rotalia* or *Pulvinulina*, one may find that the fascinating streaming of the protoplasm in the pseudopodia does not continue in the inner parts of the

protoplasm within the chambers. This protoplasm hardly moves. Therefore secreted substances, arising from the nucleus which in most stages of life is situated in the first coil of chambers, will not appear soon after their formation on the surface of the shell. I suppose that there are two kinds of substances secreted by the nucleus, viz. digestive ferments and substances which influence the secretion of chalk-substance. The digestive ferments are used in the chambers, but the latter substance, either chalk-substance itself, or, which is more probable, some ferment, which to the organism gives an opportunity to precipitate the chalk out of the sea-water, is always necessary in large quantities on the surface of the shell, as the chalk occurs in very small quantities in the sea. So it is necessary that in larger shells quickly streaming protoplasm runs from the inner parts of the shell to the surface, carrying the chalk-ferment along with it. When reaching the surface, these streams of protoplasm will either project into pseudopodia, or they will run directly along the surface of the shell. At this moment the ferment will perform its task and chalk-masses will be formed. So it is clear, that secondary chalk is found in the neighbourhood of the openings of the canals, viz. in the case of *Operculina* at the sutures and the marginal coil. These ornaments are closely connected with the quantity of chalk in the water. The formation of spines in several species of Foraminifera is always due to this canal-system, and in cases, in which no canalsystem exists, other measures have been taken (see *Tinoporus*), or large quantities of organic matter replace the chalk (*Alveolina*, f. i.). As the canalsystem and the building of chalk-masses show a close connection, and, as will be pointed out, when dealing with *Heterostegina operculinoides*, even the secondary chamberwalls are built in connection with the structure of the canalsystem, the knowledge of this system must be of considerable systematical value.

Genus **Heterostegina.**

This genus is characterised by the subdivision of the operculine chambers into secondary chamberlets. In some forms, such as *H. costata* d'Orbigny and *H. operculinoides* nov. spec., in microspheric forms these chamberlets are only indicated by the beginning of the interseptal canalsystem of the secondary walls, in species such as *H. suborbicularis* d'Orbigny they are fully developed in all forms.

The canalsystem shows the typical nummulitical development.

In lower organised species the chambers are flattened and scarcely embracing in the centre, in higher forms the central chambers are involute. The later convolutions ordinarily form a very thin lamina, surrounding the more thickened central part.

As the chambers show the foramina only in a single plane, rows of chamberlets in other directions than that of the spiral plane are never formed. This is, on the contrary, the case with the extinct genus *Spiroclypeus*, whose typical forms, in the median plane, do not form the characteristics of *Cycloclypeus*, as the name would suggest, but those of *Heterostegina*. *Spiroclypeus* is a *Heterostegina* with rows of chamberlets nearly perpendicular to the median plane. It is possible that *Spiroclypeus* is a type, descending from the embracing forms of *Operculina* with secondary foramina not exclusively placed in the median plane, whereas *Heterostegina* shows the higher type of forms, with flat spiral and a single row of secondary foramina, of the *Operculina* group.

1. *Heterostegina operculinoides* nov. spec. Pl. XXXIV; Pl. XXXVI, figs. 1, 2, 4, 5.

Heterostegina depressa Chapman, Journ. Linn. Soc., Zool., vol. XXVIII, 1900—1903, p. 19, pl. 3, fig. 6.
Heterostegina costata d'Orbigny, For. foss. Vienne, 1846, p. 212, pl. XII, figs. 15—17.

Stat. 77. 3° 27′ S., 117° 36′ E., 59 m.; 2 microsph. spec., 8 megalosph. spec.
Stat. 114. 0° 58′.5 N., 122° 55′ E., 75 m.; 12 microsph. spec., 1 megalosph. spec.
Stat. 260. 5° 36′.5 S., 132° 55′.2 E., 90 m.; 1 microsph. spec., 2 megalosph. spec.

Brief characteristics:

Forma A_1. Typical heterostegine, with flat spiral of chambers, first coils narrow, later coils suddenly broadening, thus forming a broad, very thin flange. Centre of the shell with irregularly arranged knobs of shell material. Secondary chamberlets well developed. Central chamber about 100 μ. Diameter of the shell up to 12 mm.

Forma B. Secondary chamberlets not developed, but in transmitted light the beginning of secondary walls is visible. Canalsystem also showing the commencement of interseptal canals of the secondary walls. The microsphere has a diameter up to 45 μ, the shell about 10 mm. The walls and the central part show well developed buds of secondary chalk material, forming rows of tubercles along the chamberwalls.

Two forms can easily be distinguished: the microspheric generation and the megalospheric one; possibly two forms of the megalospheric kind can be found.

We will first describe the microspheric generation, being the most primitive. This form will at first sight be identified with a large microspheric *Operculina*, with a very broad last coil. The embryonic apparatus is overgrown with a thick knob of supplemental skeleton with irregularly heaped warts of chalk; these little protuberances are also found on the chambers of the later coils, two or three rows on each chamber. The spiral of chambers is bounded by a marginal cord, which is similar to that of *Operculina*. This form resembles the type of *Operculina bartschi* Cushman very much. The diameter of the whole shell is up to 12 mm. in my material. The most striking characteristic of this form is the absence of secondary chamberlets. The typical *Operculina*-shape of the microspheric shell shows the close relationship of the two genera. The chambers are connected with each other by basal foramina, which resemble those of *Operculina*, and further by a row of secondary foramina at distinct distances. Between two secondary foramina lies a thickening of the outer chamberwall and an outgrowth into the following chamber of the suture-wall, exactly as is the case in some Operculinae. The thickening of the outer walls ends in little branches and the outgrowth of the separating walls shows us the beginning of the building of chamberlets. On the branches the chamberwall is much thicker and the pores bend sideways in this place, so that clear shell substance is formed. One would suppose, that a stream of chalk-substance had been poured out between the secondary foramina, directed towards the following chamber; this may be true, for a canal opens at the base of each little tree of chalk.

This leads us on to the canalsystem itself.

The microsphere has a diameter of about 45 μ, and is first followed by $\pm$ 32 operculine chambers, then by the broader convolutions. The first spiral is narrow and forms 4 coils. The first canals show the typical operculine shape: a spiral of anastomosing canals, which forms two branches in each chamberwall; but only the last convolution of the first 32 chambers shows a typical marginal cord. The first 32 chambers only show the principal foramen. The wall between two chambers is pierced by two canals which originate from the spiral canal, run along the principal foramen, stream through the wall to the periphery of the shell and debouch into the canals of the outer marginal cord. Here they branch off into a network of canals, most of which are directed to the mouthside of the shell and connected with the marginal canals, forming thus a triangular mass of supplemental chalk at the angles of the chambers.

As we saw in *Operculina*, the two canals in the chamberwalls form branches to the surface at equal distances, opening at the sutures and forming chalk masses there, which, if these little canals grow, form the beginning of secondary chamberwalls. In microspheric specimens this is always the case, for, in later chambers, secondary foramina are always formed and between each two of these, a clew of canals is formed by the principal chamberwall-canal, and this clew opens on the surface by means of a short canal at the suture. But in most cases, one of these canals of the clew runs further on into a narrow, ramifying, but blind-ending canal, always directed to the following chamber. From these canals originate the branched thickenings of the outer walls. But the canal, opening at the suture, was always found at the base of the branched canal. It is obvious, that a further outgrowth of this canalsystem and the accumulation of secondary chalk masses around it will build the partitions forming the secondary chamberlets, which are met with in the megalospheric form and are characteristic of all Heterosteginae. So here we have a beautiful illustration of the fact, that in Foraminifera the microspheric form of a species always shows primitive characteristics; it is the more striking, as these characteristics show us the close relationship between *Heterostegina* and *Operculina*. I therefore named the species *H. operculinoides*.

The megalospheric forms begin with a central chamber of about 100 μ diameter, followed by two kidney-shaped chambers of equal size; the angles between them are filled up with little chamberlets. These chambers are followed by a broad spiral, the chambers of which soon divide into chamberlets. These chamberlets are typically characteristic of *Heterostegina*; but here and there the secondary walls are incomplete and in these cases the canals, which transverse these incomplete walls are exactly the same as those which are built in the microspheric form. So it is clear, how these walls must be looked upon. Thus at the base of each wall separating two chamberlets is found the basal canal; it begins in the chief canal, runs in the chamberwall, continues its way slantingly to the surface and opens at the suture. The other canals, which build a little tree in the microspheric form, here run in the secondary walls to the following chamberwall-canal and end in that canal. These chamberwall-canals are mostly found double, running down to the marginal cord, as is the case in the microspheric form, but they are more irregularly shaped. At the outer ends of the big chambers the chamberlets are more triangular and the secondary walls with their canals find their origin in the marginal cord. These canals are even found in the microspheric forms, forming little outgrowths of chalk from the cord into the interior part of the chamber; these canals are mostly bifurcated at their inner ends

which, I think, open into the chambers. In the megalospheric specimens they run as two canals through the walls of these triangular chamberlets to the canals of the following chamberwall.

The two canals in the walls of the chamberlets form little branches, running upward and downward to the surface of the shell; they open into the sutures of the secondary walls.

As the canals of the chamberlet-walls originate in the canals found in the microspheric form just between each two secondary foramina, it will be obvious, that in most cases these foramina now open into a single chamberlet. But it is quite possible, that two foramina of the same row of chamberlets melt together and open as a single foramen into a chamberlet of the following row.

It is dubious, if *H. tuberculata* of MÖBIUS [1]) may be identified with our species; but the characteristics MÖBIUS mentioned ("Das Keimzentrum liegt gewöhnlich nicht in dem Mittelpunkte der Scheibe; ..... der ganze centrale Schalentheil ist auf beiden Seiten mit Tuberkeln besetzt") are not sufficient to identify it. And the "bedeutende Konvexität des Keimbuckels" does not refer to our species. There are, on the other hand, some reasons to believe, that the specimens, CUSHMAN [2]) described under the name of *H. depressa* D'ORBIGNY, var. *tuberculata* MÖBIUS, belong to our *H. operculinoides*, for he says on this subject: "usually also the central portion is slightly thickened, the remaining part of the test being flat and complanate".

The microspheric form has already been described and figured by CHAPMAN [3]), but has incorrectly been ascribed to *H. depressa*. We will show that the microspheric form of *H. depressa* has a totally different shape, as has already been described by LISTER (1902). Apparently CHAPMAN has found the two species at Funafuti, but has taken the whole species *H. operculinoides* for the microspheric generation of *H. depressa*, for he says (p. 19—20): "Form A_2 has a thin and transparent, or translucent, shell-wall and thus the septation can be clearly seen. The earlier portion shows no secondary septation dividing the chambers into chamberlets; but after two whorls of the shell have been completed, and while the test is still small, rudimentary secondary septation begins at the peripheral angles of the chambers after the manner of D'ORBIGNY's *Heterostegina simplex*". This must be wrong, for our species far more shows the characteristics of D'ORBIGNY's *H. costata*: "The next stage in the septal division is seen after the completion of about 4 whorls, when straight, bar-like, but incomplete cross-septa are seen projecting from the septum proper, but which do not extend for more than $^2/_3$ across the chamber-cavity. In many specimens this incomplete septation is apparent to within the last few chambers, when it takes on the usual characteristic secondary septation of the Heterostegine type ..... The surface of the shell in this form (B) is usually granulate. When the granules are arranged, as is sometimes the case, along the septal lines, we have the variation named by D'ORBIGNY *H. costata*". So it is possible that this species of the closely allied form already lived in tertiary age and has been described under the name of *H. costata* by D'ORBIGNY.

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1) MÖBIUS, K., Beiträge zur Meeresfauna der Insel Mauritius und der Seychellen, Berlin (1880, p. 107—108, Pl. XII, figs. 3—7).
2) CUSHMAN, J. A., 1921, l. c., (Bull. 100, U. S. Nat. Mus., vol. 4).
3) CHAPMAN, F., Foraminifera from Funafuti (Journ. Linn. Soc., London (Zoology), vol. XXVIII, 1902).

2. *Heterostegina suborbicularis* d'Orbigny. Pl. XXXV; Pl. XXXVI, figs. 3, 6—12.

Heterostegina suborbicularis d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 305; FORNASINI, Bull. Soc. Geol. Ital., vol. 22, 1903, pl. 14, fig. 6; CUSHMAN, Bull. 100, U. S. Nat. Mus., vol. 4, 1921, p. 385; CUSHMAN, Dep. Marine Biology, Carn. Inst. Wash., vol. XXI, 1924, p. 51.

Heterostegina depressa d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, 1826, p. 305, pl. XVII, figs. 5—7, Modèle n° 99.

Heterostegina antillarum d'Orbigny, 1839, Foraminifera. In: Ramon de la Sagra, Hist. Phys., Politique et Nat. de l'île de Cuba, Paris, p. 122, pl. VII, figs. 24, 25; see for further literature: HERON-ALLEN and EARLAND, For. of the Kerimba Archipelago, Trans. Zool. Soc., London, vol. XX, pt. II, 1915, p. 738.

Heterostegina curva Möbius, Beitr. zur Meeresfauna etc., 1880, p. 105—107, pl. XIII; see for further literature: MILLET, XI. Report Malay Archipelago, Journ. Roy. Micr. Soc., Dec. 1904, p. 606.

Heterostegina depressa (d'Orbigny) RHUMBLER, Foraminiferen v. Laysan etc., Zool. Jahrbücher, vol. XXIV, 1906.

Stat. 43. Anchorage off Pulu Sarassa, Postillon-islands, up to 36 m.; one microsph. spec.
Stat. 64. Kambaragi-bay, Tanah Djampeah, up to 32 m.; one megalosph., with large first chamber, one microsph. spec.
Stat. 160. North Coast of Kofiau-island, near Kampong Hebera, 31 m.; 2 microsph., some megalosph. spec.
Stat. 184. Anchorage off Kampong Kelang, South coast of Manipa-islands, 36 m.; about 20 megalosph. spec.
Stat. 226. 5° 26′.7 S., 127° 36′.5 E. 1595 m.; about 40 megalosph. spec.
Stat. 315. Anchorage East of Sailus Besar, Paternoster-islands, up to 36 m.; one microsph. spec.

Brief characteristics of the species:

Forma A_1. Test lenticular, very similar to forma A_2, but without curved sutures of the alar prolongations and without distinct umbilical chalk. Flange more flattened and somewhat curved.

Forma B. Test very large, up to 15 mm. and more, with thick central part without any structure, later coils broadening and forming a curved flange. First spiral with undivided chambers, first chamber 27 μ.

Forma A_2. Test lenticular, with scarcely developed flange. Centre with hyaline knob, filling up the umbilicus; alar prolongations of the central chambers curved. Diameter of proloculum about 130 μ, that of the shell 3—4 mm.

Three forms have been found in the material, two belonging to the megalospheric, one to the microspheric generation.

The two megalospheric forms possess initial chambers of different sizes, the larger having a diameter of about 130 μ, the other possessing a diameter of about 80 μ. The individuals with the largest initial chamber are identical with *Heterostegina suborbicularis* d'Orbigny in CUSHMAN's description: "Test free, central portion thickened and involute; peripheral portion thin especially towards the periphery; subdivisions of the chambers not appearing until the flange is developed; wall smooth. Diameter up to 4 mm." (Samoan Foram. 1924, p. 51). In about the seventh chamber the first chamberlets appear.

The microspheric form of our species can be best identified with some specimens of *Heterostegina suborbicularis* which CUSHMAN described in 1921, when he said: "Its whole

appearance is very different from that of *H. depressa*, it being much thicker, strongly biconvex in the central portion, which is thin near the periphery.... Specimens attain a growth of 8 mm. and more". Microspheric specimens have already been described by LISTER (1903, p. 129), and he says, that the microsphere has a diameter of 27 μ, and is followed by about 36 simple chambers before the septa appear. This is a very peculiar fact for, as we showed in *H. operculinoides*, the Heterosteginae originate from Operculinae and here the microspheric form once more shows the most primitive characteristics.

The third form is, as we mentioned already, a megalospheric form with an initial chamber of about 80 μ diameter and has been figured by LISTER (fig. 56, A). The tests are more lenticular than those of "*H. orbicularis*", the later whorls are thin and the septa appear in the 9th or 10th chamber. This form often shows characteristics of microspheric specimens and I believe that there are also intermediate specimens between this form and the megalospheric with large embryonic chamber. The diameter is up to 5 mm. and the flange of the last whorl of chambers is often curved, as in the microspheric form. So I am sure that MÖBIUS' species *H. curva* can be identified with this form. The form is named a variety by EGGER and has been described by other authors as *H. depressa* d'Orbigny itself. As in some forms of *Operculina* the undivided chambers of the first convolutions show alar prolongations, the thickness of the central part of the shell is due to this phenomenon. As the prolongations are somewhat irregularly shaped, there is some resemblance with *Amphistegina* with respect to the first coils.

The canalsystem shows the same characteristics as that of megalospheric *H. operculinoides*, so that a few figures will suffice to give some details. One of the slides also shows the furrow on the periphery of the chambers, in which the chief canal of the marginal cord runs further on, just as is the case in *Operculina*.

Genus **Cycloclypeus**.

This genus, by recent authors considered to belong to the subfamily of the Cycloclypeinae, must be looked upon as a true Nummulitic genus. CUSHMAN (1925, p. 50) also classes with it the ORBITOIDAE, Orthophragminae, Lepidocyclinae and Myogypsinae. Whether *Orthophragmina* is a real Nummulitide or not I cannot say, for the canalsystem of that genus has not yet been studied and I could not obtain sufficiently preserved material to do it now. *Lepidocyclina*, *Myogypsina* and *Orbitoides*, with their raspberry type of embryonic apparatus in megalospheric form, belong to the Planorbulinae. As I have already pointed out, the genus *Spiroclypeus* probably belongs to the group of *Heterostegina*.

Foraminifera with typical heterostegine arrangement of the first chambers in microspheric specimens show in megalospheric specimens a somewhat confused spiral arrangement of the embryonic chambers, due to their very large development. The later cyclical arrangement of the chambers is very typical. The canalsystem shows the nummulitical characteristics.

1. *Cycloclypeus carpenteri* Brady. Pl. XXIV, fig. 1; Pl. XXXVII; Pl. XXXVIII, figs. 1—9, 12, 13.

Cycloclypeus Carpenter, Philos. Trans., vol. 146, 1856, p. 555, pl. 30, figs. 1 and 3; Introduction Foram., 1862, p. 292.

Cycloclypeus carpenteri H. B. Brady, Quart. Journ. Micr. Soc., vol. 21, 1881, p. 67; Rep. Voy. Chall., Zool., vol. 9, 1884, p. 751; LISTER, Philos. Trans., vol. 186 B, 1895, p. 437—438, pl. 9, figs. 52—54; CHAPMAN, Journ. Linn. Soc., vol. 28, 1900, p. 22. pl. 2, figs. 6, 7; pl. 3, figs. 1—5.

Cycloclypeus guembelianus H. B. Brady, Quart. Journ. Micr. Soc., vol. 21, 1881, p. 66; Rep. Voy. Chall., Zool., vol. 9, 1884, p. 751, pl. 111, figs. 8 *a*, *b* (young form); CUSHMAN, U. S. Nat. Mus., Bull. 100, vol. 4, 1921, p. 386—387.

Stat. 49ª. 8° 23′.5 S., 119° 4′.6 E., 69 m.; 47 megalospheric specimens, 1 microspheric.
Stat. 57. 10° 29′ S., 121° 28′.7 E., 1419 m.; 1 megalospheric specimen.
Stat. 65ª. Near 7° 0′ S., 120° 34′.5 E., from 400 m.; 8 megal. specimens.
Stat. 152. Wunoh-bay, N. W.-Coast of Waigeu-island, 32 m.; numerous megalospheric and microsph. specimens.
Stat. 154. 0° 7′.2 N., 130° 25′.5 E., 83 m.; numerous specimens.
Stat. 257. In Du-Roa-strait, Kei-islands, till 52 m.; one microspheric specimen.
Stat. 260. 5° 36′.5 S., 132° 55′.2 E., 90 m.; one megalospheric specimen.
Stat. 262. 5° 53′.8 S., 132° 48′.8 E., 560 m.; one megalospheric young specimen.

Brief characteristics:

Shells with cyclically arranged later coils of chambers. All forms show flat, pan-cake shaped shells, the middle of which is somewhat thickened. Shell-substance very hard and of a white colour. Protoplasm orange by symbiotic algae.

Forma A_1. Size of the shells about 6 mm. Shell very thin, secondary chalk only covering the centre with little knobs, later chambers with thin walls, distinctly visible. Megalosphere 150 μ diameter.

Forma B. Large shells, up to 60 mm. diameter. Only the centre covered with thick secondary chalk; edge of the shell very thin and flattened. First chamber ± 30 μ, followed by 10 operculine chambers, succeeded by heterostegine ones. Later chambers cyclical.

Forma A_2. Normal shells with a diameter of about 8 mm. First chamber ± 450 μ, followed by two kidney-shaped chambers. Later chambers cyclical. Walls of these later chambers covered with secondary chalk. Many individuals are plural, and have a larger size.

As BRADY gave to the larger forms of this species the name of *C. carpenteri*, and these larger forms appeared to be microspheric, I have preferred to give to all forms this name, and not the name of *C. guembelianus*, as CUSHMAN does.

The species is only distributed in the eastern part of the Archipelago.

Two forms are found in the Siboga-material and exactly as LISTER [1]) describes them, but according to my theory of heterogamy a third form was also found, with a small megalosphere. One of them is the microspheric generation, and even LISTER suggests, that "the specimens, which attain the large size are microspheric". These specimens of which several examples could be studied, attain a diameter of about 60 mm. The centre of the disk is lenticular, but the greater part of the shell is flattened and very thin, so that undamaged specimens are very rare.

The microsphere has a size of about 30 μ and is succeeded by a spiral of 10 simple

1) LISTER, J. J., 1903, l. c. (p. 130—132, fig. 57).

chambers, which show the operculine characteristics. The following chambers are shaped more irregularly and show the form of those of *Heterostegina*. Finally the 24th chamber encircles the preceding ones completely; and in this way the typical cycloclypeine chambers appear. Here again we find, that in its first coils the microspheric generation undoubtedly shows the characteristics of the supposed ancestors of the species.

The inner shape of the shell corroborates this view. Firstly the chamberlets of an annular chamber are connected with those of the following chamber by means of two foramina each, in such a way, that each chamberlet is connected with two chambers of the following row. Often the two foramina of two neighbouring chamberlets come together before they reach the chamberlets of the following chamber. So here we find the same thing which we already stated in *Heterostegina*, in which all secondary foramina bifurcated in the direction of the initial chamber (the arrangement of the chambers has also been described by LISTER, 1894). Secondly the canalsystem shows all the characteristics of that of *Heterostegina*, only the marginal cord is reduced and is only met with in the first coils of the shell, forming the periphery of the operculine-heterostegine spiral. This cord is only represented by a set of irregular canals and disappears when it forms the chamberwall-canals of the annular chambers. These chamberwall-canals are regularly developed in microspheric individuals, forming two ringshaped canals, each of which runs dorsally or ventrally from the secondary foramina. They anastomose and form little canals running to the surface and opening into the chamber-sutures.

A second system of canals forms the canals of the walls of the secondary chambers. In each secondary wall run two of them, each of which is formed by the combination of two canals, running in the chamberlet walls of the foregoing row and also connected with the first canalsystem. In this way a peculiar network with honey-comb mashes is formed and within these mashes lie the secondary chambers. The secondary canals form smaller ones, which run obliquely to the surface and open alternately on either side of the sutures. This secondary canalsystem is nothing but a somewhat higher developed heterostegine system. Never is the canalsystem, as CARPENTER thought, in any way connected with the chambers. The canalsystem has been described and figured already by K. MARTIN [1]). The radially running canals ("interseptal-Kanäle") have very accurately been described by this author.

The megalospheric forms show a very large initial chamber, with a diameter of about 400—500 μ, and possess a diameter of only 8 mm. It is this form which has been described as *C. guembelianus* Brady, and the secondary chalk mass, which forms the centre of the shell, is not so highly developed as in the microspheric form. The large megalosphere is surrounded by a short spiral of two kidney-shaped large chambers in such a manner, that the centre is "somewhat resembling the primitive disc of *Orbitolites complanata*" (LISTER). They are surrounded by some irregularly arranged heterostegine chambers, but are soon followed by the typical cycloclypeid arrangement. The canalsystem begins with a primitive marginal cord only round the first chambers, and is then followed bij the cycloclypeid system, which has already been described. The canals are much narrower than in the microspheric form.

A very interesting peculiarity was stated in some megalospheric specimens, viz. animals

1) MARTIN, K., Die Tertiärschichten auf Java, Leiden, 1880, (Pl. XXVII, figs. 1*c*, 2*a*, 3*b*; Pl. XXVIII, fig. 1*h*).

with more than one embryonic apparatus. Some of these abnormal individuals had two sets of initial chambers and a diameter of about 12 mm., and some possessed three sets and a diameter of 16 mm. In the genus *Orbitolites* RHUMBLER [1]) found such abnormal shells and gave them the name of univalent plural individuals. Yet these individuals in the case of *Cycloclypeus* are not at all univalent, though the arrangement of the later chambers does not differ from that in normal shells. The surfaces (and, as the shells are equally thick, the volumes are so, too) of the individuals with one, two and with three embryonic apparates show a peculiar ratio viz. 81 : 144 : 256, or about 1 : 2 : 3. So it is obvious that an individual with three embryonic sets of chambers also has the value of three individuals. RHUMBLER did not find this difference in size in the univalent shells of *Orbitolites*. So it seems to be a peculiarity of *Cycloclypeus* only.

JENSEN observed [2]), that in *Orbitolites* the pseudopodes of older individuals never fuse in normal circumstances, but the young ones, having just escaped from the parent, easily melt together. We may suppose that these young specimens which consist of a part of the protoplasm of the parent and have just formed a single individual, show a high affinity, as the pseudopodes of a single full-grown individual also easily melt together. VERWORN [3]) saw, that artifically formed parts of a Foraminiferum also easily do so.

The first chambers of the embryonic apparates in plural individuals always lie close to each other and the kidney-shaped chambers are directed to the periphery of the shell.

In one specimen five sets of embryonic chambers were met with. Yet this specimen was not much larger than those with three initial chambers.

The third form is distinguished from the normal megalospheric specimens by its very thin shell. The secondary chalk only covers the centre, as in microspheric forms, and no knobs of chalk are seen on the chamberwalls in later rings, as is the case in the megalospheric form with a large first chamber. The megalosphere of these specimens, which are never abundant in our samples, measures about 150 μ.

The protoplasm in fixated specimens fills up only the centre of the shell and forms radiating branches towards the periphery. Often a green or yellow colour was seen and in this case the protoplasm was filled up with little corpuscules, probably symbiotic algues.

In megalospheric individuals the large, vacuolised nucleus lies in the first chambers, sometimes it is found in all chambers as little chromatic masses.

In microspheric forms distinct chromatic masses are found in nearly all chambers, except in the outer regions of the shell. In the canalsystem clear protoplasm was met with.

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1) RHUMBLER, L., Die Doppelschalen von *Orbitolites* und anderen Foraminiferen, etc. (Archiv für Protistenkunde, Vol. I, 1902)

2) JENSEN, O., Über individuelle physiologische Unterschiede zwischen Zellen der gleichen Art (Archiv. d. ges. Physiologie. Vol. 62, 1895, p. 172—200, pt. I and II).

3) VERWORN, M., Biologische Protisten-Studien (Zeitschr. f. wiss. Zool., vol. 46, 1888, p. 455).

Family AMPHISTEGINIDAE.

In most of the recent systematical works on Foraminifera the genus *Amphistegina* is placed in the neighbourhood of *Nummulites* and considered as an aberrant group of the NUMMULITIDAE. There are, however, no reasons to do so, for only the nautiloid shape of the shell, which moreover is not even a perfect one (most species showing unsymmetrical forms) can be mentioned as a nummulitic characteristic. For though CHAPMAN [1]) says that *Amphistegina* possesses a real canalsystem, there will now be no doubt about the absence of such a system in all Amphisteginae. This is a very important difference between the two genera *Amphistegina* and *Nummulites*, and, I must say, it is the only remarkable difference. Therefore I am sure that many fossil Amphisteginae have been described as *Nummulites*, the canalsystem being very difficult to study in fossil material, due to imperfect preservation (so RUTTEN and DOUVILLÉ showed, that *Nummilites niasi* Verbeek is really some species of *Amphistegina*). When we study transverse sections, it is easy to state a difference between *Amphistegina* and *Nummulites*. In *Nummulites* the primitive canal of the marginal cord forms an indentation in the marginal part of each chamber; this indentation is not found in *Amphistegina*. As higher *Nummulites* show the same deep constrictions forming supplementary lobes of the chambers, it is possible, that *Nummulites* and *Amphistegina* descend from the same ancestors. It is possible that SCHUBERT's [2]) carboniferous species *Nummulostegina velebitana* from the neoschwagerina limestone of Austria, represents such an ancestral type though YABE [3]) does not believe it to be a real *Amphistegina*, but some relation of *Nummulites cumingi*. The fact is, that microspheric individuals of *Amphistegina* show a more equal shape of the shell (nummulitic shape) than megalospheric ones.

Characteristics of the family:

Test spiral and lenticular, in most species more convex on one side than on the other, especially in megalospheric forms, and on the more convex side the last convolution covers the others. Chambers numerous and possessing alar prolongations, mostly divided by deep constrictions so as to form lobes, but sometimes simple on both sides or on the less convex side of the shell Umbilicus mostly filled up with clear chalk; sometimes the walls show papillae or little

1) CHAPMAN, F., The Foraminifera: An Introduction to the study of the Protozoa, London, 1902, p. 233.

2) SCHUBERT, R. J., Beiträge zu einer natürlichen Systematik der Foraminiferen (Neues Jahrb. für Mineralogie u. s. w., Beilageband XXV, 1908).

3) YABE, H., Notes on Operculina-Rocks from Japan etc. (Science Reports of the Tohôku imperial University, Sendai, Japan ser. 2 (Geology), vol. III and IV, 1918, p. 126).

spines, but generally they are very smooth. Pores always very fine and numerous, no canal-system at all. A single aperture at the base of the chamber, symmetrical.

Genus **Amphistegina** d'Orbigny, 1826.

Characteristics the same as those of the family.

In this genus only very few species have been stated. The three recent "species", which have been mentioned by various authors, appear to belong to one and the same species. This species has also been found in most tertiary regions. Another fossil species, *A. Fleuriausi* from the senonian beds of Maestricht, has recently been studied by the author and was found to be a true *Amphistegina*, though BRADY (Chall. Rep., p. 743) and YABE [1]) thought that it was an *Operculina* [2]).

There is some possibility that the forms, described by D'ORBIGNY [3]) under the names of *Amphistegina hauerina* and *A. mamillata*, form a different genus with a striking difference between the two sides. Here I must mention the fact, that in most general works on Foraminifera and in Zoological and Palaeontological Textbooks figures are given of *A. hauerina* d'Orbigny as a typical species of *Amphistegina*. The concave side with its simple chambers, however, forms in this species a very exceptional characteristic never met with in most of the common species, such as *A. radiata*.

1. *Amphistegina radiata* Fichtel et Moll. Pl. XXIX; Pl. XXX, figs. 2, 3, 4, 6, 7.

Nautilus radiatus Fichtel et Moll, 1798.
Nautilus radiatus (Nummulina) Parker et Jones, 1859, Ann. Mag. Nat. Hist., 1860, p. 105—106.
Amphistegina radiata Chapman, Proc. Zool. Soc. (London), 1895, pp. 45—47, pl. 1, figs. 8—10, 12.
Amphistegina lessonii, var. *radiata* (Fichtel et Moll) Heron-Allen and Earland, Trans. Zool. Soc. London, vol. XX, pt. II, 1915, p. 736; CUSHMAN, 1914, U. S. Nat. Mus., Bull. 71, pt. 4, p. 35 (here further literature).
Amphistegina lessonii d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 304, n° 3, pl. 7, figs. 1—4; MÖBIUS, 1880, Foram. Mauritius, p. 99, pl. X, figs. 10—14, pl. XI, figs. 1—3; BRADY, 1884, Foram. Challenger, Zool., IX, p. 740, pl. CXI, figs. 1—7; CHAPMAN, 1900, Journ. Linn. Soc. London (Zool.), vol. XXVIII (1902), p. 204; CUSHMAN, 1914, U. S. Nat. Mus., Bull. 71, Pt. 4, p. 35; idem, Bull. 100, vol. 4, 1921, p. 370.
Amphistegina lessonii d'Orbigny, var. *Madagascariensis* d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 305, n° 5; FORNASINI, Rend. Acad. Sci. Bologna, vol. 7, 1903, p. 144, pl. 2, fig. 5; HERON-ALLEN and EARLAND, Trans. Zool. Soc. London, vol. 20, 1915, p. 736; CUSHMAN, U. S. Nat. Mus., Bull. 100, vol. 4, 1921, p. 372.

Stat. 59. 10° 22'.7 S., 123° 16'.5 E., 390 m.
Stat. 64. Kambaragi-bay, Tanah Djampeah, up to 32 m.
Stat. 65a. Very near 7° 0' S., 120° 34'.5 E., 510 m.
Stat. 104. Sulu harbour, Sulu island, 14 m.
Stat. 133. Anchorage off Lirung, Salibabu-island, up to 36 m.
Stat. 154. 0° 7'.2 N., 130° 25'.5 E., 83 m.
Stat. 164. 1° 42'.5 S., 130° 47'.5 E., 32 m.

1) YABE, H., 1918, l. c., p. 107.
2) HOFKER, J., Die Foraminiferen aus dem Senon Limburgens (Natuurhist. Maandblad, Maastricht, Jaarg. 15, 1926, n° 3, p. 29—31; n° 7, p. 80—82).
3) D'ORBIGNY, 1846, For. Foss. Vienne, p. 207—208, Pl. XII, figs. 1—3, 6—8).

Stat. 184. Anchorage off Kampong Kelang, Manipa-island, 36 m.
Stat. 220. Anchorage off Pasir Pandjang, west coast of Binongka, 278 m.
Stat. 226. 5° 26'.7 S., 127° 36'.5 E., 1595 m.
Stat. 240. Banda-anchorage, 9—45 m.
Stat. 250. Anchorage off Kilsuin, west-coast of Kur-island, 20—45 m.
Stat. 258. Tual-anchorage, Kei-islands, 22 m.
Sikka, Flores.
Kwandang 1914, leg. NOUHUYS.

Characteristics of the species:

Test nearly biconvex and lenticular, of white colour, with sharp margin.

Forma A_1. Both sides nearly identical, only on one side chambers somewhat simpler. Chambers numerous, umbilicus not large, chambers with sharp angles. Diameter ± 1.5 mm.

Forma B. Both sides nearly identical, chambers very symmetrical, with sharp angles and with highly developed secondary lobes. Large umbilicus. Diameter up to 4 mm.

Forma A_2. Unsymmetrical, one side more convex than the other, on the latter side chambers not reaching to the umbilicus, so that the chambers of earlier convolutions are visible. Chambers not numerous, and simple on the flattest side. Diameter ± 1 mm.

I found three forms in the Siboga-material, just as CUSHMAN [1]) found them in the Philippine-collections. Two of these forms, A_1 and A_2, were megalospheric, the third microspheric.

The test is nearly biconvex and lenticular. The number of the chambers of the last whorl differs in the three forms: in forma A_1 this number is from 19 to 24, in forma A_2 15 or 16, in the microspheric form about 30 (even to 35).

The centre of the shell shows a large umbonal clear space, especially in forma A_2 (Pl. XXIX, fig. 3). The pores of the chambers are very narrow and have their mouths in groups on the surface, but these groups do not correspond exactly with the supplementary lobes of the chambers. The chambers are equitant (Pl. XXIX, fig. 9); the alar prolongations on one side are more simple (Pl. XXX, fig. 2), on the other side they are divided into lobes by deep constrictions and openings (Pl. XXIX, fig. 8). The middle of the chambers is low and with a sharp prolongation backward (Pl. XXX, fig. 2) and they communicate with one another by means of a single median foramen. In most forms the alar lobes show an edge near to the periphery which is formed owing to the prolongation of the middle of the chamber; so the sharp angle is directed forward.

As the "sutures" on the surface of the shell mostly find their origin in the fact that the mouths of the pores are absent in these places, and as the place of the pores does not always correspond with the inner lobes of the chambers, only casts of shells, as I could make them by means of my canadabalsam-method, can be studied for systematical purposes.

This species is but little inequilateral; the alar prolongations of the chambers are nearly equally highly developed on either side of the shell. These prolongations are very flat; the

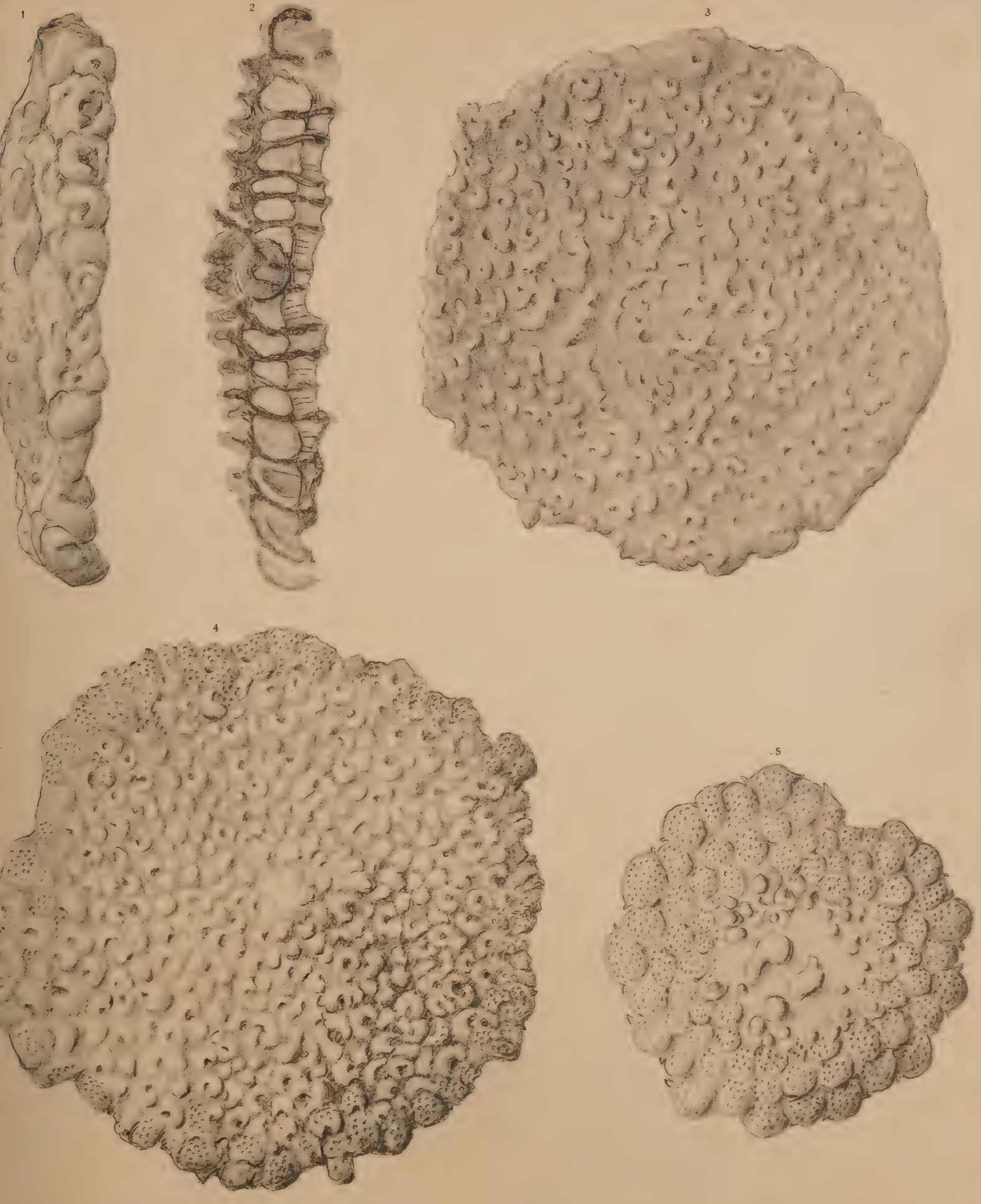
1) CUSHMAN, J. A., 1921, l. c., p. 372.

EXPLANATION OF THE PLATES.

PLATE I.

Planorbulina larvata.

Fig. 1. Side-view of megalospheric shell; × 34.
Fig. 2. Transverse section of this shell. The megalosphere was filled up with protoplasm; × 34.
Fig. 3. Lower side of megalospheric shell; × 34.
Fig. 4. Dorsal side; × 34.
Fig. 5. Young microspheric individual; × 34.

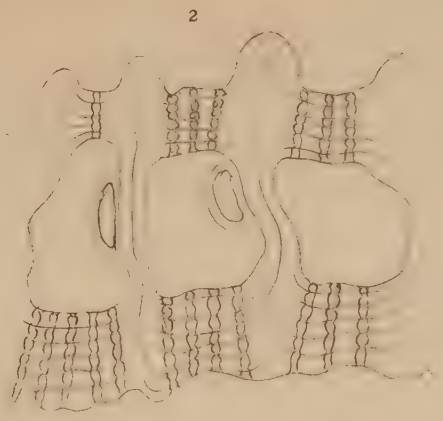


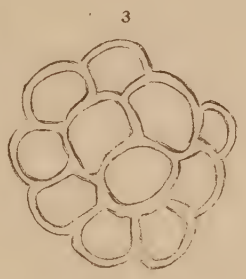
PLANORBULINA LARVATA.

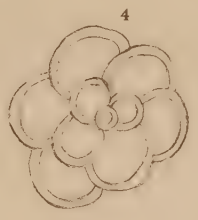
PLATE II.

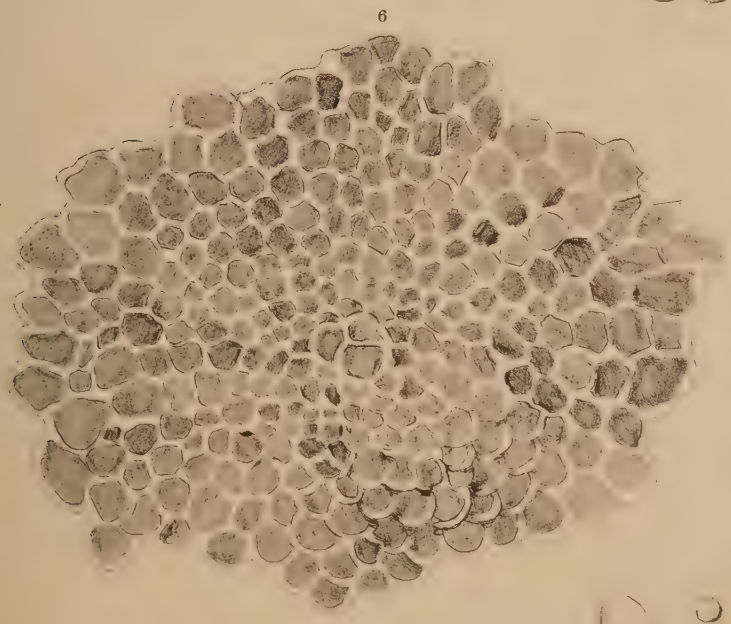
Planorbulina larvata.

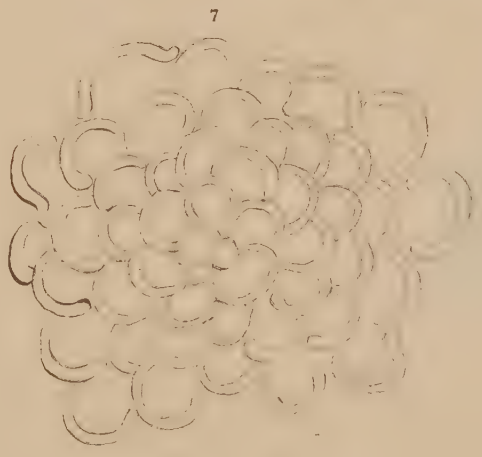
Fig. 1. Microspheric specimen, horizontal section. Some of the walls are double; × 115.
Fig. 2. Transverse section through three chambers; × 375. Two of them show a foramen; the walls between the chambers are double; the foramina very clearly show the periodical increase of the walls.
Fig. 3. Megalospheric first set of chambers, raspberry-type; × 115.
Fig. 4. Microspheric first set of chambers; × 115.
Fig. 5. Megalospheric first set of chambers, forma A_1; × 115.
Fig. 6. Horizontal section through a specimen, filled up with some dark sulfuric matter; forma A_2, × 60.
Fig. 7. Megalospheric specimen, horizontal section; forma A_1, × 115.
Fig. 8. Schematic figure of a canadabalsam-preparation of some of the chambers, showing their foramina; × 230.
Fig. 9. Transverse section, showing the thickened lips of the foramina; × 115.
Fig. 10. Canadabalsam-preparation of the chambers, showing their ventral lobes, foramina and pores; × 450.

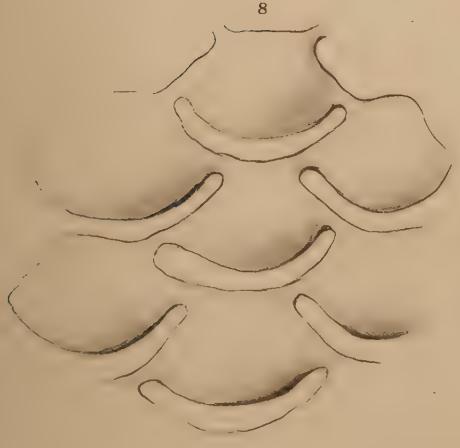


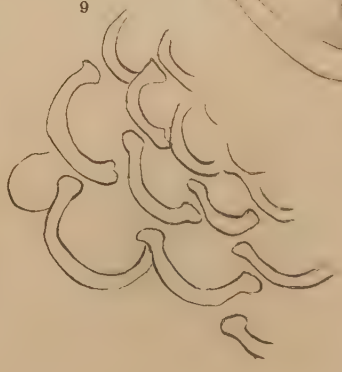


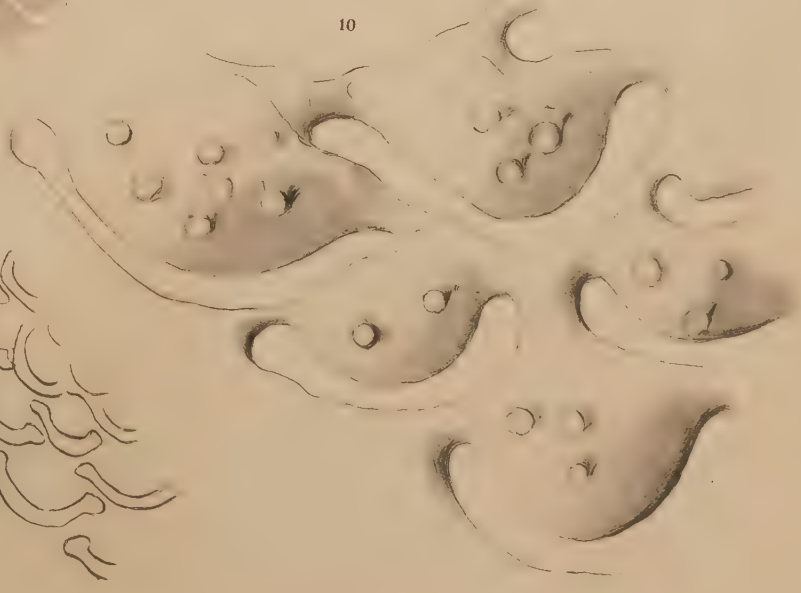










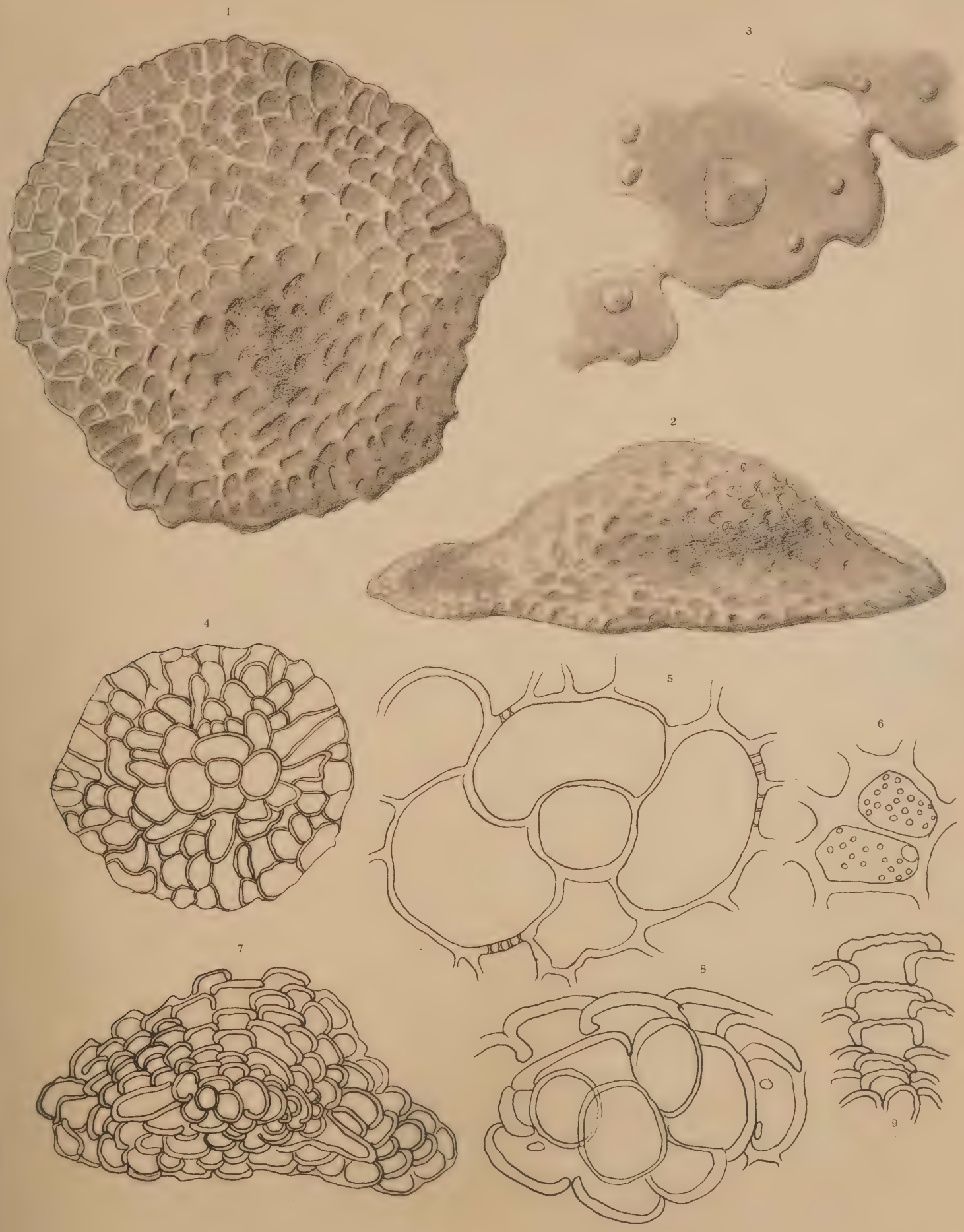


PLANORBULINA LARVATA.

PLATE III.

Gypsina vesicularis.

Fig. 1. Large specimen, seen from above; × 28.
Fig. 2. The same, from aside; × 28.
Fig. 3. A piece of thallus of *Halimeda*, with individuals of *Gypsina*; × 5.
Fig. 4. Horizontal section through first chamber; × 115.
Fig. 5. The same section, centre, enlarged; × 210.
Fig. 6. Chambers with pores and a foramen; × 210.
Fig. 7. Vertical section; × 115.
Fig. 8. The same section, central part; × 210.
Fig. 9. Part of vertical section, more highly magnified, to show the arrangement of chamberrows; × 210.

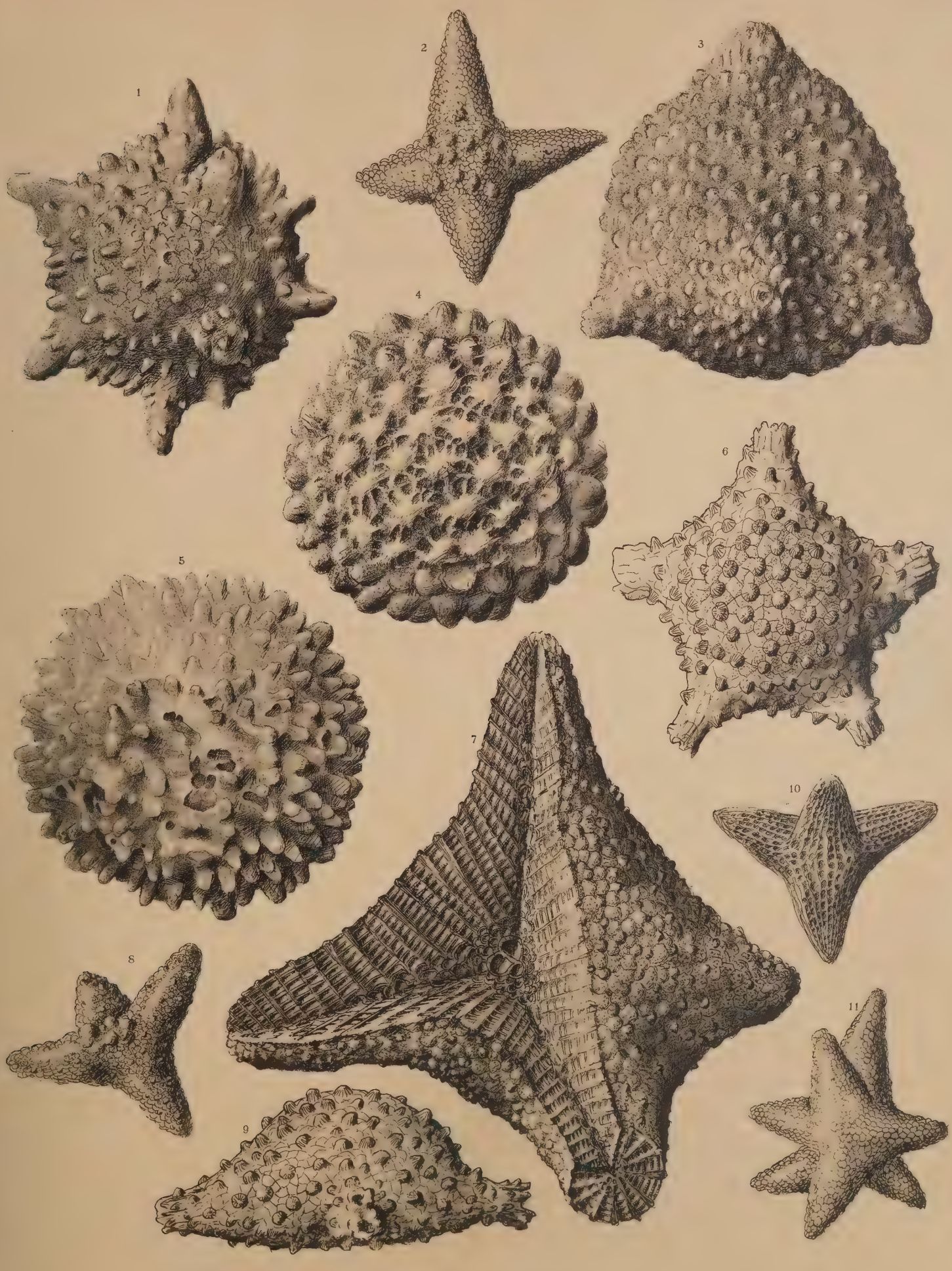


GYPSINA VESICULARIS.

PLATE IV.

Tinoporus baculatus and *T. Floresianus.*

Fig. 1. *T. Floresianus*, forma B, young; × 27.
Fig. 2. *T. baculatus*, forma A_2, specimen with four spines, directed in a single plane; × 15.
Fig. 3. *T. Floresianus*, forma A_2; × 27.
Fig. 4. *T. Floresianus*, forma A_1; × 27.
Fig. 5. *T. Floresianus*, forma B; × 22.
Fig. 6. *T. baculatus*, forma B, dorsal view; × 18.
Fig. 7. *T. baculatus*, forma A_2, specimen showing the inner structure; × 38.
Fig. 8. *T. baculatus*, forma A_2, with gigantic chambers; × 15.
Fig. 9. *T. baculatus*, forma B, side-view; × 18.
Fig. 10. *T. baculatus*, eroded specimen; × 15.
Fig. 11. *T. baculatus*, forma A_2, irregular specimen; × 15.



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TINOPORUS BACULATUS. T. FLORESIANUS.

PLATE V.

Tinoporus baculatus and *T. Floresianus.*

Fig. 1. *T. Floresianus*, canadabalsam-preparation of a section through one of the spines, showing the arrangement of the surrounding chambers, and the fullgrown foramina running into the chalk of the spine; × 65.

Fig. 2. *T. Floresianus*, detail of surface, showing chamberwalls and secondary chalk masses, forming the top of column, forma A_1; × 300.

Fig. 3. *T. Floresianus*, chambers and columns, forma A_2, surface; × 180.

Fig. 4. *T. Floresianus*, schematic figure of the arrangement of chambers, pores and foramina; × 180.

Fig. 5. *T. baculatus*, section through nucleus, filled up with granules of chromatin; × 225.

Fig. 6. *T. baculatus*, section through older nucleus; chromatin concentrated near the surface of the nucleus; × 225.

Fig. 7. Section through *T. baculatus*, showing gigantic chambers; × 75.

Fig. 8. Schematic figure of canadabalsam-preparation of *T. baculatus* showing a column surrounded by rows of chambers; × 180.

Fig. 9. *T. Floresianus*, canadabalsam-preparation of the surface, forma A_1; × 180.

Fig. 10. *T. baculatus*, nucleus showing chromatin arranged near the surface; × 330.

Fig. 11. *T. Floresianus*, chambers with nuclear masses in the protoplasm; × 225.

Fig. 12. Embryonic apparatus of *T. Floresianus*, seen from above. The first coils of irregularly arranged chambers are also visible; × 180.

Fig. 13. Section through a spine of *T. Floresianus*, showing surrounding chambers with their pores and going straight through some of the stoloniferous foramina; × 450.

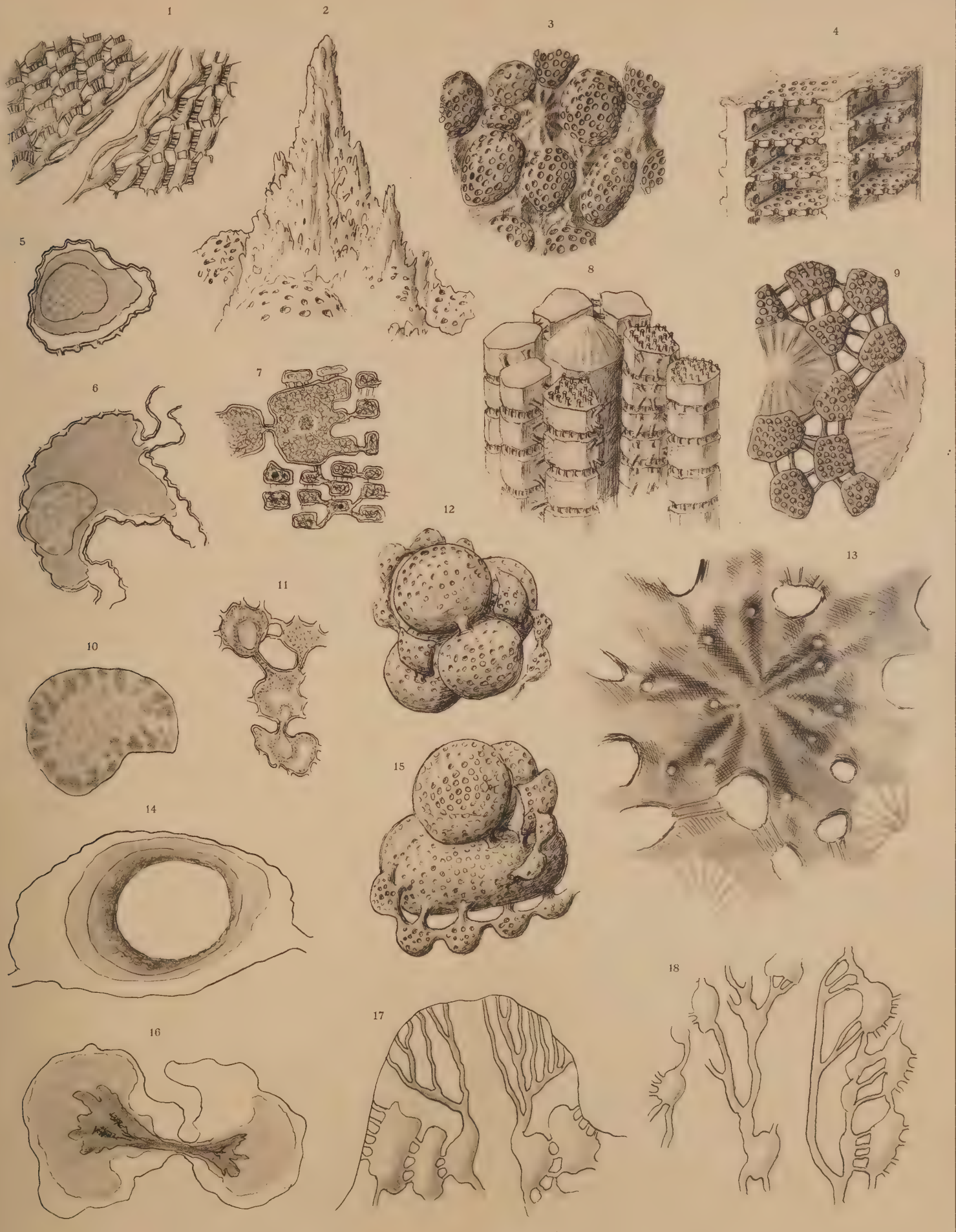
Fig. 14. Section of old nucleus, with large vacuole, having lost most of its chromatin; × 330.

Fig. 15. Embryonic apparatus, seen from aside; × 180.

Fig. 16. Nucleus showing amoeboid form in second and third chamber; × 225.

Fig. 17. End of a spine, with chambers and pseudo-canals; × 225.

Fig. 18. Irregularly shaped chambers and foraminal canals in the middle of a spine; × 225.



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TINOPORUS.

PLATE VI.

Tinoporus baculatus and *T. Floresianus.*

Fig. 1. *T. Floresianus,* forma B; × 3.
Fig. 2. *T. Floresianus,* forma A_1; × 3.
Fig. 3. *T. Floresianus,* forma A_2; × 3.
Fig. 4. *T. baculatus,* forma A_2 and B; × 3.
Fig. 5. *T. Floresianus,* forma A_1. Canadabalsam-preparation showing chamberrows and a column; × 90.
Fig. 6. *T. Floresianus,* decalcified section through a spine; × 75.
Fig. 7. *T. Floresianus,* decalcified section, embryonic apparatus; × 60.
Fig. 8. *T. baculatus,* decalcified, section through young nucleus; × 150.
Fig. 9. *T. Floresianus,* forma A_1, canadabalsam-preparation, section through the middle; × 15.
Fig. 10. *T. Floresianus,* section showing chromatinous masses in the protoplasm; × 150.
Fig. 11. *T. Floresianus,* canadabalsam-preparation, showing a row of chambers with their pores; × 180.
Fig. 12. *T. baculatus,* section through a spine with a gigantic chamber; × 37.
Fig. 13. *T. baculatus,* section through megalospheric specimen, × 23.
Fig. 14. Initial chambers of the same individual, more highly magnified; × 85.
Fig. 15. *T. Floresianus,* same section as fig. 7, showing nucleus with peripherical heaps of chromatin; × 115.
Fig. 16. *T. Floresianus,* canadabalsam-preparation, showing the arrangement of the foramina; × 150.
Fig. 17. *T. Floresianus,* another canadabalsam-preparation; × 180.
Fig. 18. *T. Floresianus,* protoplasm with heaps of chromatin substance; × 120.
Fig. 19. *T. baculatus,* decalcified section through a spine; × 70.
Fig. 20. *T. Floresianus,* canadabalsam-preparation with spine; × 15.
Fig. 21. *T. Floresianus,* section through microspheric specimen, showing nucleus in initial chambers; × 60.

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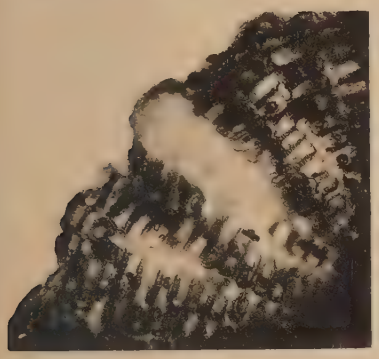
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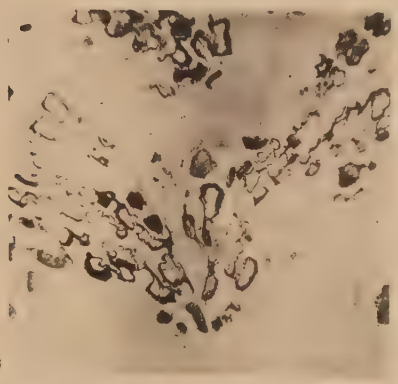
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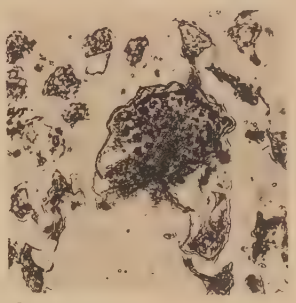
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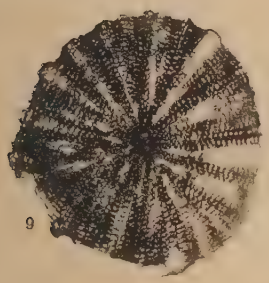
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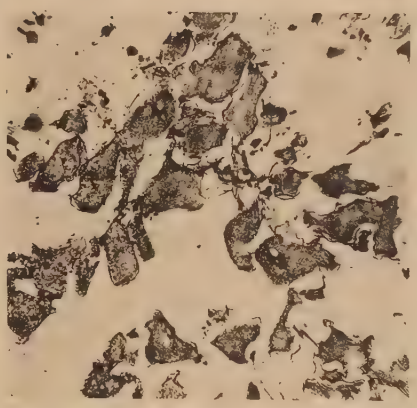
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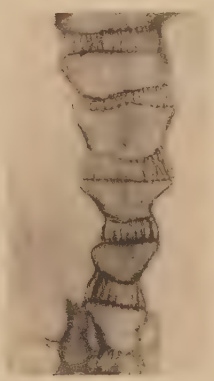
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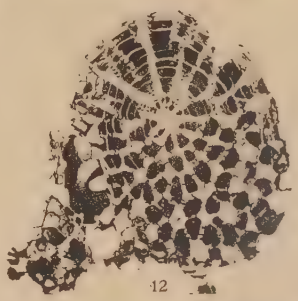
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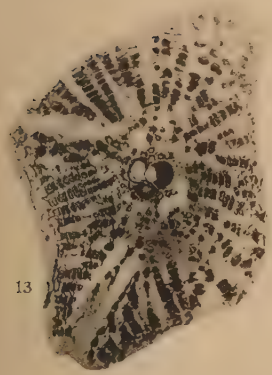
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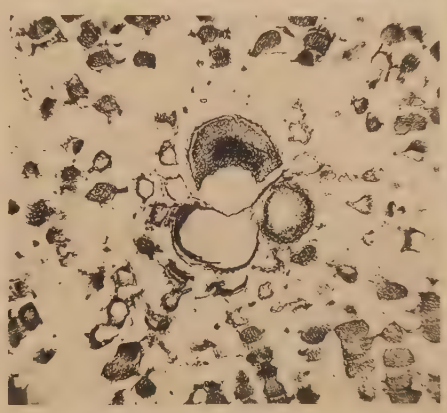
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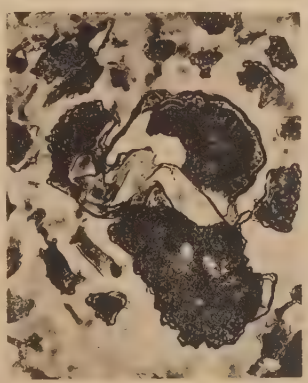
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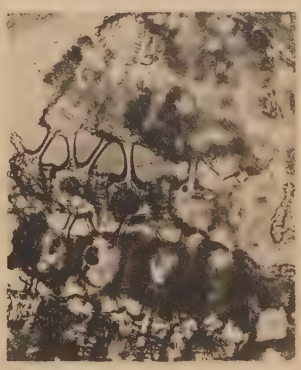
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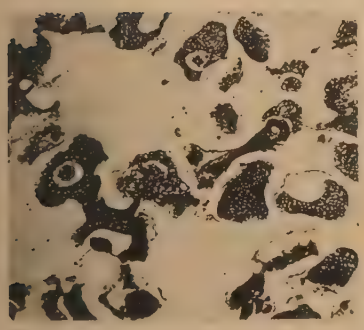
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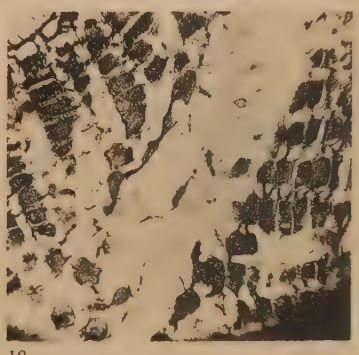
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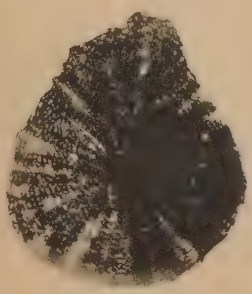
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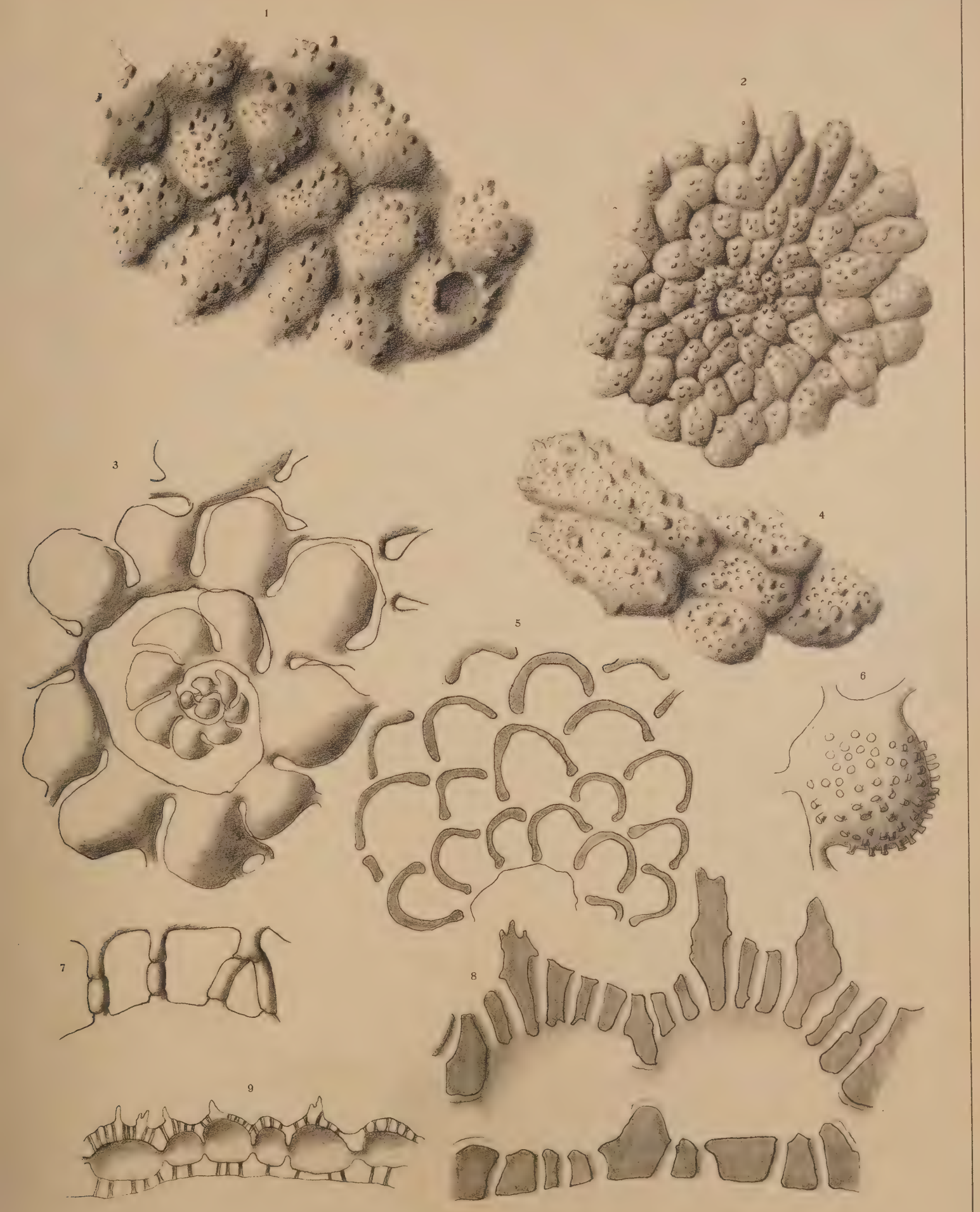
TINOPORUS.

PLATE VII.

Sporadotrema rubrum.

Fig. 1. Part of the shell-surface, showing secondary growth of the walls. One of the chamberwalls has been broken away; × 60.
Fig. 2. Whole shell; × 25.
Fig. 3. First coils of chambers, decalcified; × 110.
Fig. 4. Some of the outer chambers of the shell, showing their peculiar shape; × 60.
Fig. 5. Horizontal section through part of a shell; × 60.
Fig. 6. One of the chambers, showing pores and foramina; × 115.
Fig. 7. Pores, highly magnified, showing their melting together and traces of secondary growth of the walls; canadabalsam-preparation; × 350.
Fig. 8. Transverse section through two chambers; × 150.
Fig. 9. Transverse section through a greater part of the shell, showing dorsal and ventral pores and secondary outgrowth of the walls; × 35.



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SPORADOTREMA RUBRUM.

PLATE VIII.

Sporadotrema.

Fig. 1. *Sporadotrema mesentericum*, forma A_2; × 8.
Fig. 2. *S. mesentericum*, forma A_2, another specimen, showing some characteristics of forma A_1; × 8.
Fig. 3. *S. cylindricum*, forma A_1, × 6.
Fig. 4. *S. mesentericum*, young specimen, probably forma B, showing the set of basal chambers, followed by the first chambers of the trunk, × 25.
Fig. 5. *S. cylindricum*, forma A_2, × 6.
Fig. 6. *S. cylindricum*, forma B, × 10.
Fig. 7. *S. mesentericum*, forma B, × 8.
Fig. 8. *S. rubrum*, × 15.

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SPORADOTREMA.

PLATE IX.

Sporadotrema, Planorbulina.

Fig. 1. *Sporadotrema cylindricum*, forma B, showing the microspheric first set of chambers, decalcified.

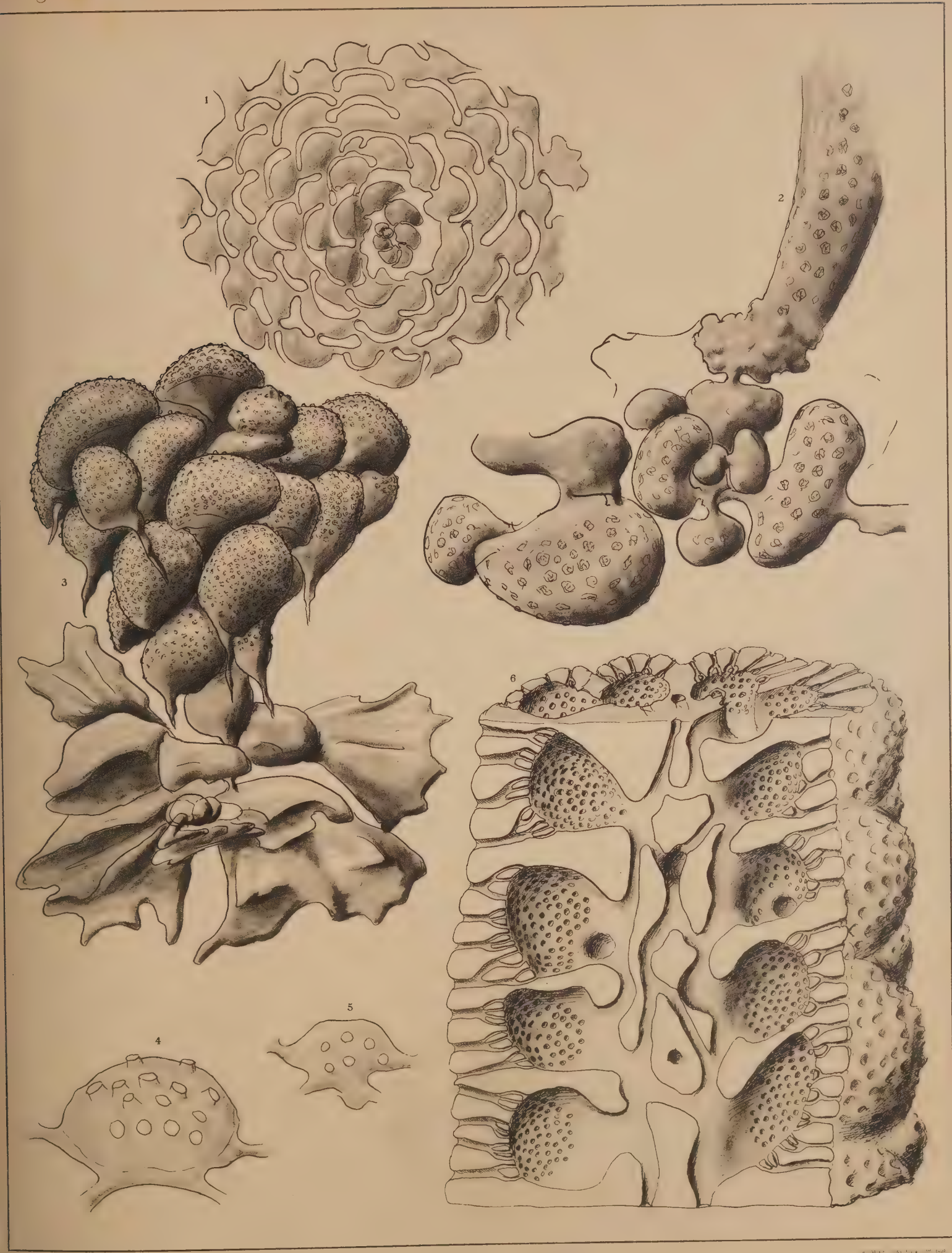
Fig. 2. *Sp. cylindricum*, forma A_2, first set of chambers, with its stolon reaching to the surface of the chalk algues.

Fig. 3. Decalcified young specimen of *Sp. cylindricum* (which was attached to a rock and not concealed in chalk algues), showing the basal chambers and the beginning of the tree.

Fig. 4. Chamber of the third coil of chambers of microspheric form of *Sp. cylindricum*.

Fig. 5. Chamber of the third coil of chambers of *Planorbulina larvata*, showing the difference in size with that of fig. 4.

Fig. 6. Schematic figure of part of the trunk of *Sp. cylindricum*, showing the chambers and the stolons in the centre of the trunk, the flowing together of the pores and the external structure of the chamberwalls.



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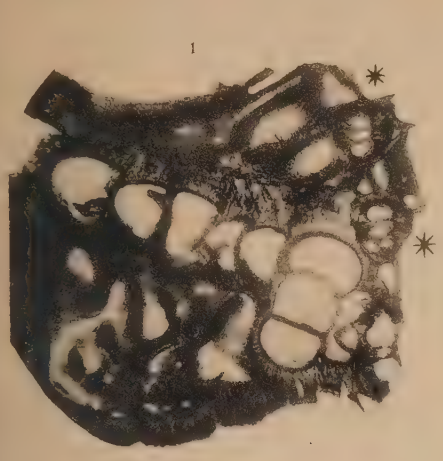
SPORADOTREMA, PLANORBULINA.

PLATE X.

Fig. 1. *Sporadotrema cylindricum*, vertical section through the trunk, showing two sets of initial chambers (* and *). Preparation of HICKSON; × 24.
Fig. 2. Same section, showing set of first chambers; × 100.
Fig. 3. Same section, showing two sets of chambers, and HICKSON's chambers i. c.; × 36.
Fig. 4. Vertical section through a trunk of *Sp. cylindricum*, showing chambers and irregular stolons between them; × 13.
Fig. 5. Transverse section; × 13.
Fig. 6. *Sp. cylindricum*, forma A_1, × 3.
Fig. 7. *Sp. cylindricum*, forma A_2, × 3.
Fig. 8. Canadabalsam-preparation, showing section through chamberwall with pores; × 27.
Fig. 9. Section through chambers of the base of the trunk, decalcified, with protoplasm. The outer chitinous walls are closed, no pores being visible; × 90.
Fig. 10. *Sp. cylindricum*, showing ends of branches with the arrangement of chambers; × 9.
Fig. 11. *Sp. mesentericum*, megalosph.; × 5.
Fig. 12. Decalcified specimen of basal part of *Sp. cylindricum*, forma A_1, showing the irregularly shaped basal chambers; × 80.
Fig. 13. Same specimen also showing the first chambers of trunk; × 31.
Fig. 14. *Sporadotrema rubrum*, decalcified specimen; × 16.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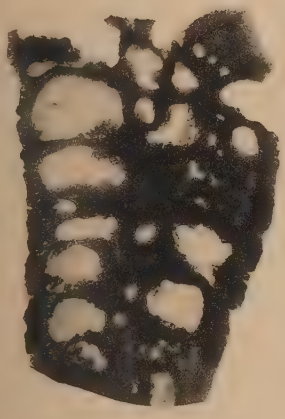
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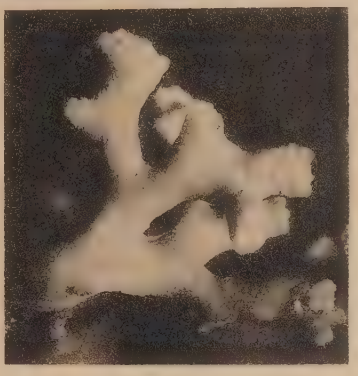
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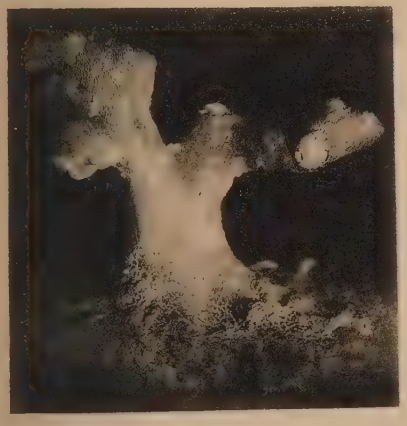
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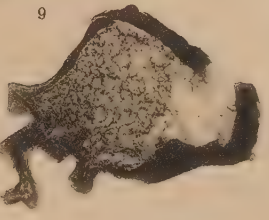

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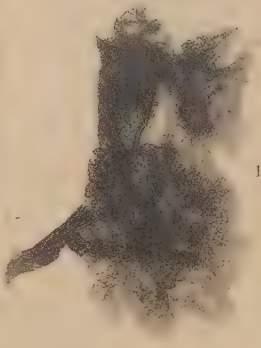
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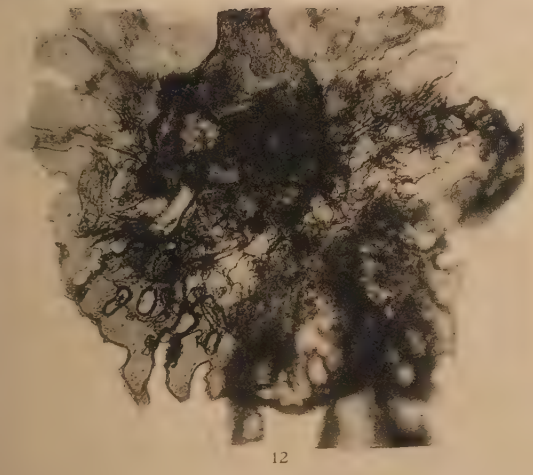
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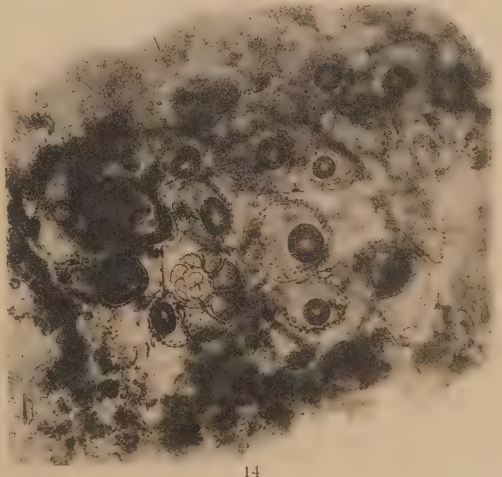
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SPORADOTREMA.

PLATE XI.

Polytrema album.

Fig. 1. Leaf of sea-weed, incrusted with colonies of *Polytrema album*; × 6.
Fig. 2. Transverse section through part of a shell, × 60; showing aperture with sponge-spicules.
Fig. 3. Single specimen with three apertures; × 18.
Fig. 4. Decalcified specimen, showing first coils of chambers; × 240.
Fig. 5. Horizontal section through decalcified specimen, showing foramina, chambers, pillars and pores; × 240.

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POLYTREMA ALBUM.

PLATE XII.

Polytrema miniaceum.

Fig. 1. Megalospheric specimen with small base; × 10.
Fig. 2. Megalospheric specimen with larger base; × 10.
Fig. 3. Microspheric specimen; × 10.
Fig. 4. The "raspberry" of initial chambers, seen from above; × 350.
Fig. 5. The same, seen from below, with coloured nucleus; × 350.
Fig. 6. Schematic section through a specimen (see Pl. XIV, fig. 6); × 200.

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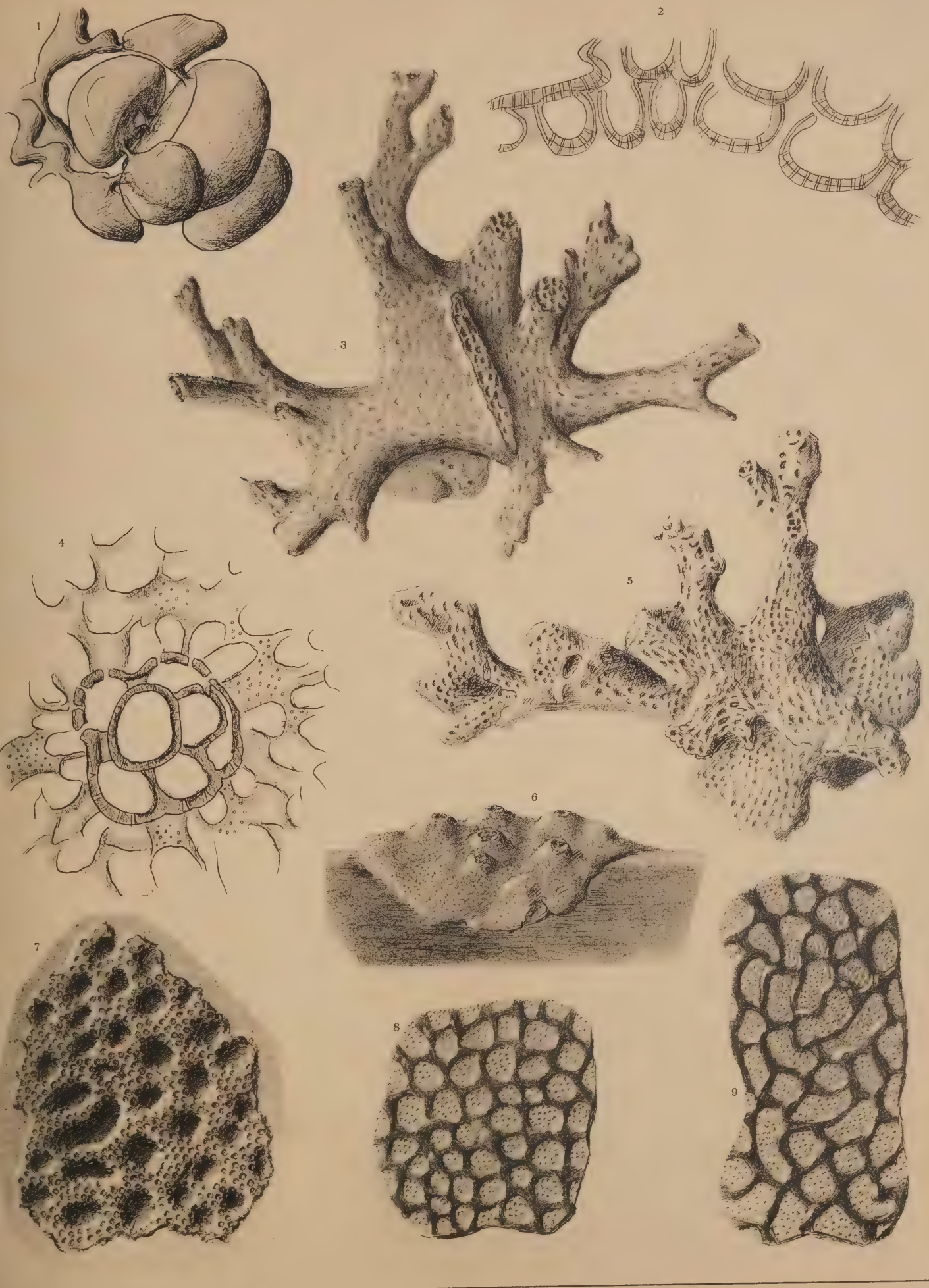
POLYTREMA MINIACEUM.

PLATE XIII.

Polytrema and *Homotrema*.

Fig. 1. *Polytrema miniaceum*, first set of megalospheric specimen, forma A_2; × 375.
Fig. 2. *Polytrema miniaceum*, part of transverse section, showing pores, "pillar-pores", double walls of pillars; × 350.
Fig. 3. *Polytrema miniaceum*, forma A_2, with fan-shaped branches; × 12.
Fig. 4. *Polytrema miniaceum*, horizontal section through initial part of megalospheric form with small first chamber, forma A_1; × 225.
Fig. 5. Microspheric individual of *P. miniaceum*; × 12.
Fig. 6. *P. miniaceum*, forma A_1; × 12.
Fig. 7. Part of surface of the shell of *P. miniaceum*; × 75.
Fig. 8. Part of surface of the shell of *Homotrema*; perhaps forma B, regular areolae; × 75.
Fig. 9. Surface of the shell of *Homotrema*, more irregularly shaped areolae; × 75.



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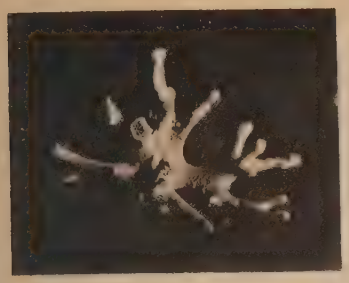
POLYTREMA AND HOMOTREMA.

PLATE XIV.

Polytrema and *Homotrema*.

Fig. 1. *P. miniaceum*, megalospheric form (forma A_2); × 5.
Fig. 2. *P. miniaceum*, on mollusc; × 5.
Fig. 3. *P. miniaceum*, forma A_1, on a sponge; × 5.
Fig. 4. *P. miniaceum*, forma A_2, young individual, first set of chambers; × 60.
Fig. 5. Horizontal section through *P. miniaceum*, showing chambers and pillars; × 30.
Fig. 6. Transverse section through young megalosph. individual of *P. miniaceum*; × 35.
Fig. 7. Section through protoplasm of *Polytrema*, showing absorbed sponge-spicules; × 180.
Fig. 8. Microspheric first set of chambers, *P. miniaceum*; × 90.
Fig. 9. *P. miniaceum*, forma A_1, transverse section; × 15.
Fig. 10. Same forma, but decalcified, showing protoplasm; × 45.
Fig. 11. Section through young specimen of *P. miniaceum*, showing sponge-spicules projecting from the mouth; × 30.
Fig. 12. Section through the stem of *Homotrema*, showing the thickened walls; × 30.
Fig. 13. Specimens of *Homotrema*, covering rock; probably forma B; × $1^1/_2$.
Fig. 14. *Homotrema*, forma A_1, on a stone; × 2.
Fig. 15. *Homotrema*, forma A_2; × 3.
Fig. 16. Megalospheric initial chambers of *Homotrema*; × 60.
Fig. 17. Protoplasm of *Homotrema*, seen in section; × 185.
Fig. 18. Transverse section through *Homotrema*, showing the so-called "pillars"; × 27.
Fig. 19. Section, showing a "pillar" with its thin perforated wall, on the surface, thus forming an areola; × 225.
Fig. 20. *Homotrema* on coral, forma A_2; × $2^1/_2$.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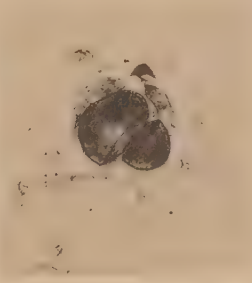
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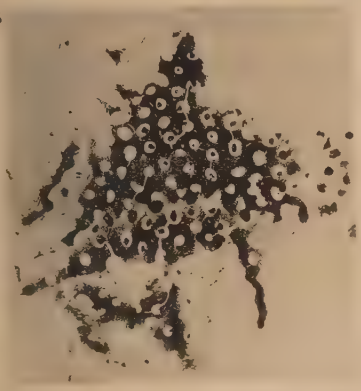
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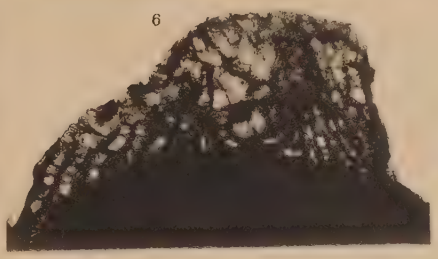
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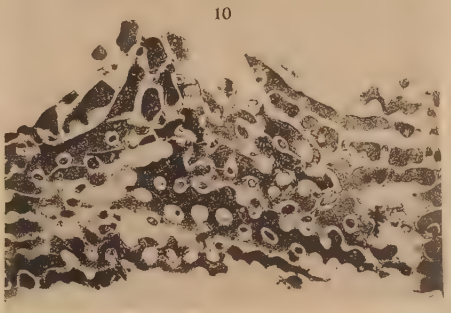
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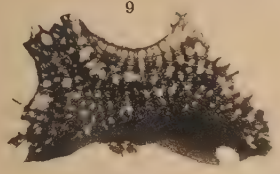
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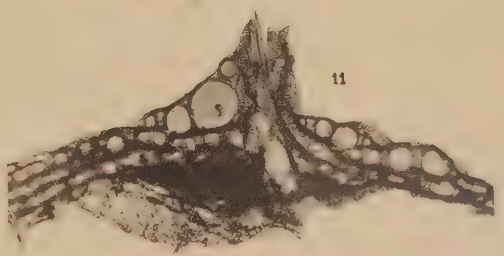
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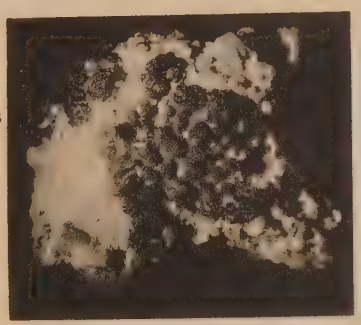
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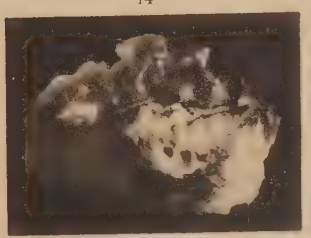
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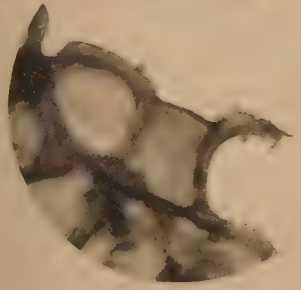
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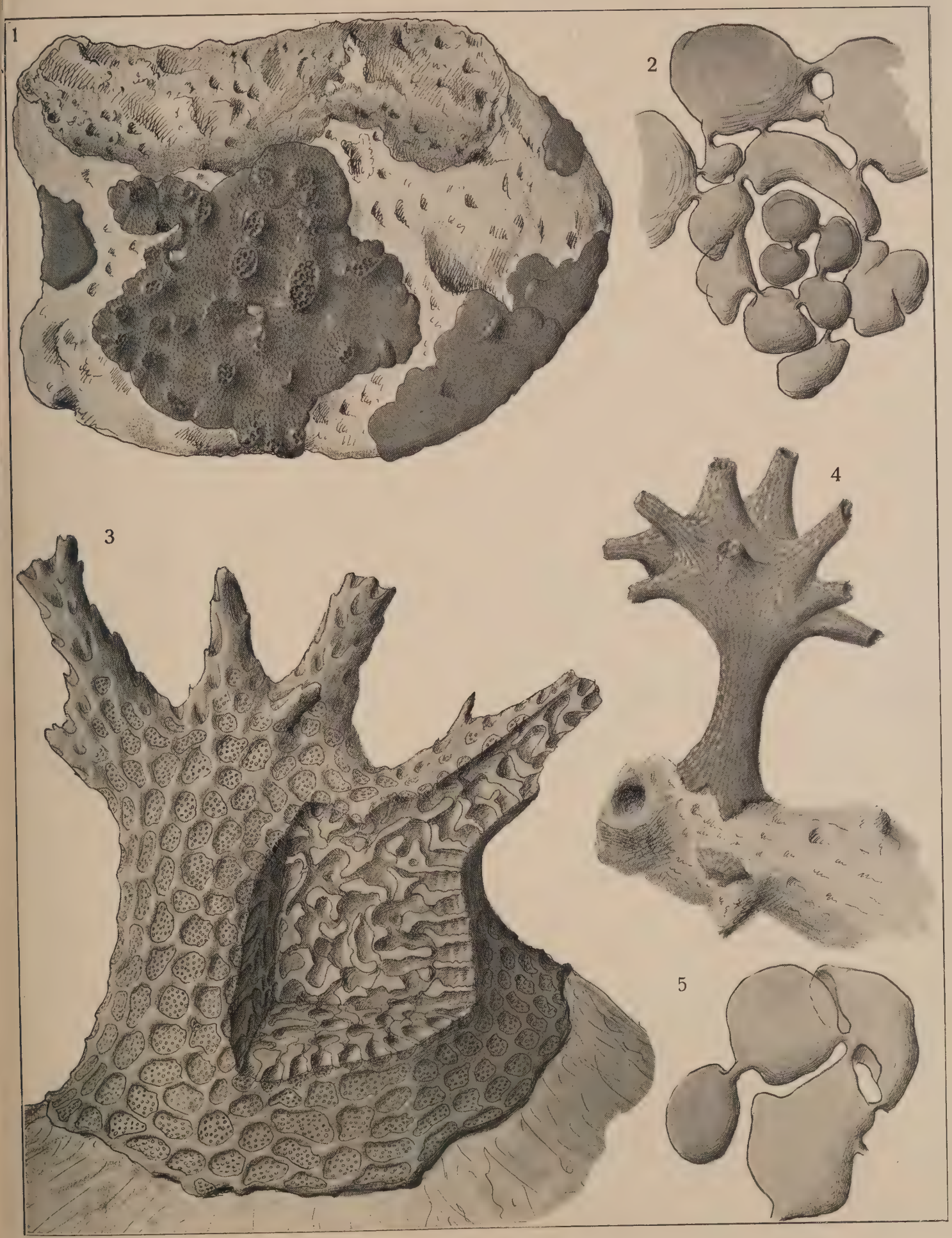
POLYTREMA AND HOMOTREMA.

PLATE XV.

Homotrema.

Fig. 1. Plurivalent specimen (possibly microspheric), on a piece of coral-rock; × 4.
Fig. 2. Megalospheric first chambers with spiral first coils, forma A_1; × 300.
Fig. 3. Specimen of forma A_1, showing areolae and inner structure, with rudiments of outer chamberwalls in superficial tubes; × 33.
Fig. 4. Specimen of forma A_2, on coral; × 9.
Fig. 5. First chambers of forma A_2; × 300.



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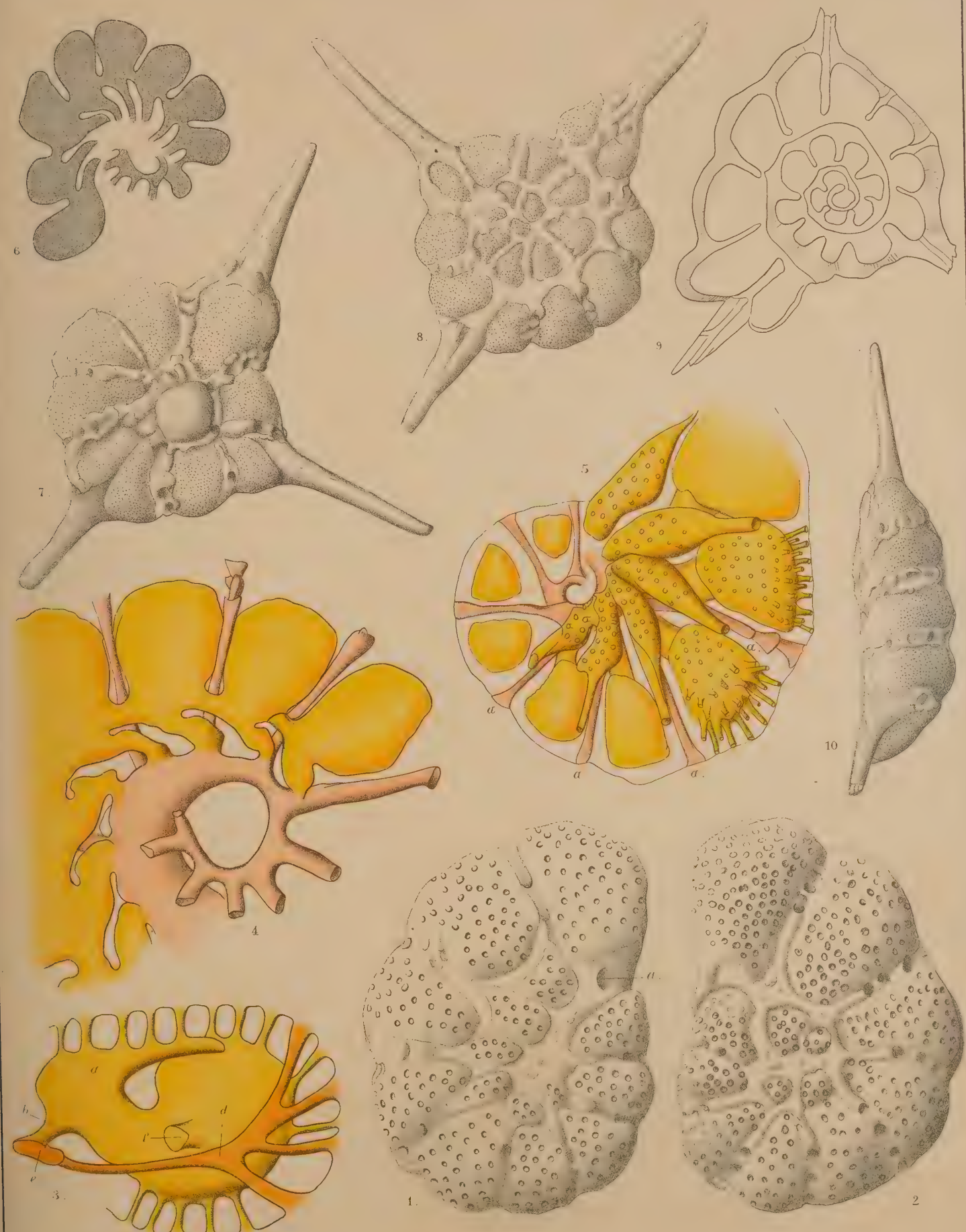
HOMOTREMA.

PLATE XVI.

Rotalia polystomelloides and *R. pulchella.*

Fig. 1. Ventral view of *R. polystomelloides*; × 120. *a*: Opening of the spiral canal.
Fig. 2. Dorsal view of the same individual; × 120.
Fig. 3. Schematic transverse section through a chamber of *R. polystomelloides* with section through spiral canal (*e*) and showing interseptal canals (*d*). Ventral side above, dorsal beneath. *a*: ventral lobe of the chamber, with its blind outgrowth, and the opening into the spiral canal *b*; *f*: foramen to the next chamber. Canadabalsam-preparation.
Fig. 4. Canadabalsam-preparation of the inner part of the test of *R. polystomelloides*, showing the spiral canal with interseptal canals, and the communication of the canalsystem with one of the rows of chambers; × 380.
Fig. 5. Ventral view of a canadabalsam-preparation of *R. polystomelloides*, showing the ventral lobes of the chambers and the ventral pores of the interseptal canals *a*; × 120.
Fig. 6. Part of a section of decalcified *R. polystomelloides*; × 120.
Fig. 7. Ventral part of the shell of *R. pulchella*; × 120.
Fig. 8. Dorsal part of the same; × 120.
Fig. 9. Section through a shell of the same specimen, showing canalsystem in the spines; × 120.
Fig. 10. Side view of *R. pulchella*; × 120.



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ROTALIA POLYSTOMELLOIDES, R. PULCHELLA.

Lith. van P. J. Mulder & Zn., Leiden.

PLATE XVII.

Rotalia calcar.

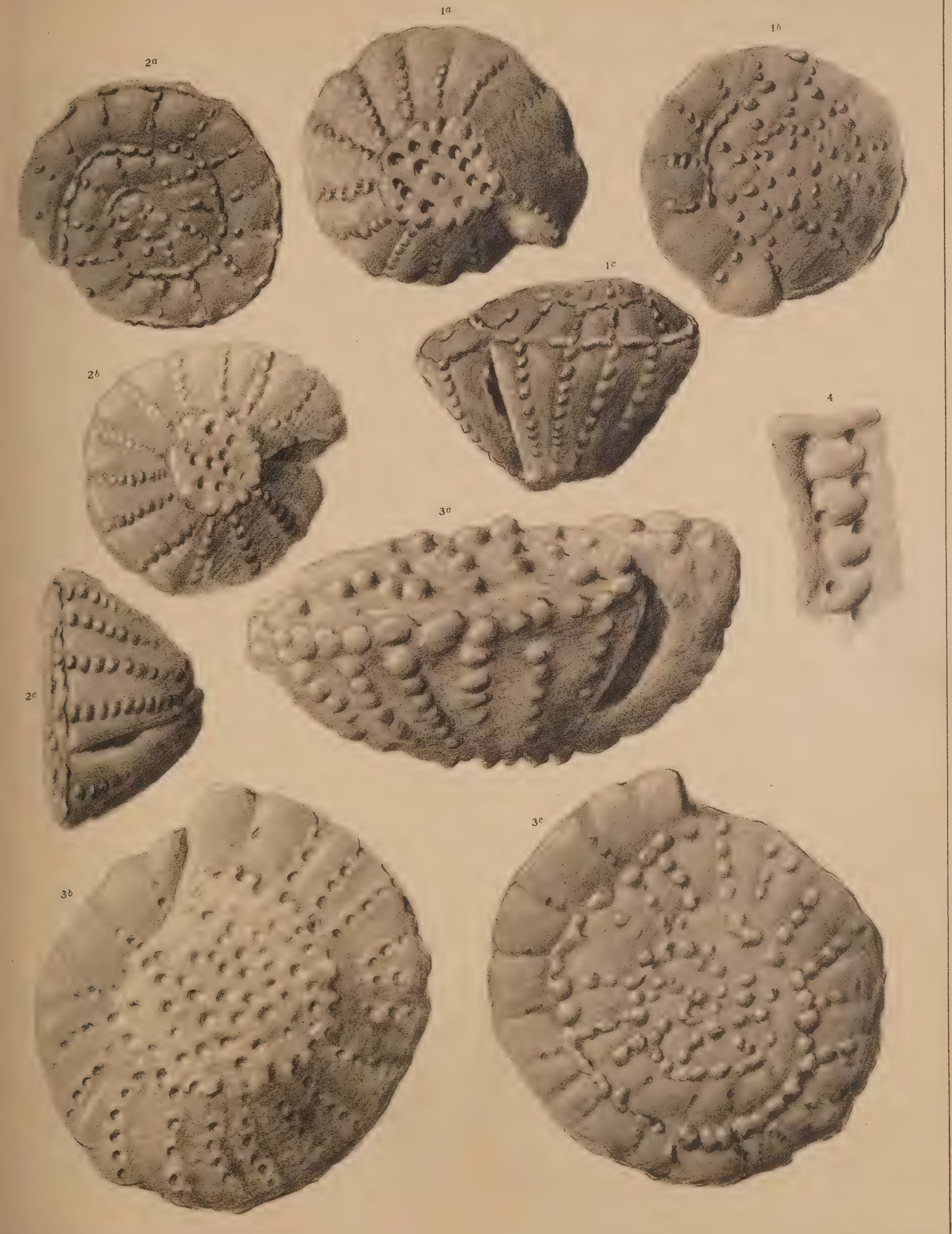
Fig. 1. Calcarine form, mouthside; × 65.
Fig. 2. Same individual, ventral view; × 65.
Fig. 3. Same individual, dorsal side; × 65.
Fig. 4. Another calcarine individual; × 65.
Figs. 5 and 6. Hispid form, ventral and dorsal side; × 65.
Fig. 7. Transverse section through the dorsal wall, showing the single perforation; × 105.
Fig. 8. Calcarine specimen with distinct sutures; × 65.
Fig. 9. Another individual; × 65.
Fig. 10. Canadabalsam-preparation of outer chamberrow and umbilical canalsystem; hispid form; × 380.
Fig. 11. Whole section through a hispid individual; × 105.
Fig. 12. Section through spiral canal and outer whorl of chambers of calcarine specimen; canadabalsam-preparation; × 140.
Fig. 13. Section through the wall of a hispid specimen; × 325.

ROTALIA CALCAR.

PLATE XVIII.

Rotalia schroeteriana.

Fig. 1, *a*, *b*, *c*. One of the megalospheric forms; × 60.
Fig. 2, *a*, *b*, *c*. Another megalospheric form with very flat dorsal side; × 60.
Fig. 3, *a*, *b*, *c*. Microspheric specimens; *b* with very little secondary development; × 60.
Fig. 4. Suture between two chambers, with openings of the canalsystem and buds of secondary chalk; × ± 250.



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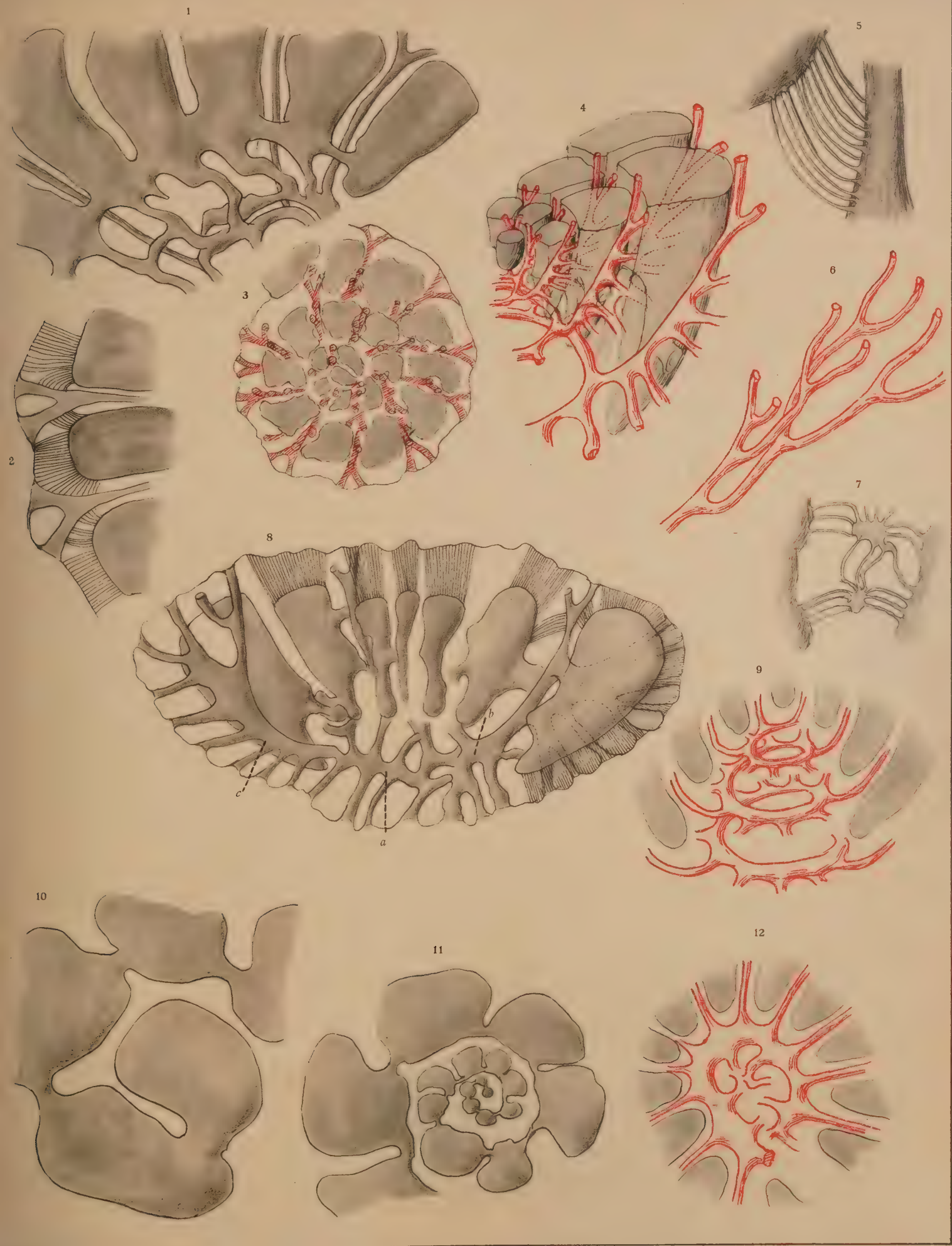
ROTALIA SCHROETERIANA.

PLATE XIX.

Rotalia schroeteriana.

Fig. 1. Canadabalsam-preparation showing ventral outgrowths of chambers communicating with umbilical canalsystem; × 125.
Fig. 2. Bifurcating ends of two interseptal canals with pores ending into them; × 125.
Fig. 3. Dorsal view of a megalospheric specimen with interseptal system of chambers; × 60.
Fig. 4. Schematic figure of chambers, spiral canal and interseptal system.
Fig. 5. Pores between chamber and canal, showing that the ends of pores always form a right angle with the surface they end in; × 320.
Fig. 6. Scheme of interseptal canals.
Fig. 7. Transverse section of two interseptal canals with pores communicating with them; × 320.
Fig. 8. Transverse section through microspheric individual; canadabalsam-preparation. *a*: umbilical system; *b*: spiral canal; *c*: interseptal canal; × 105.
Fig. 9. Schematic figure of the spiral canal with the beginnings of interseptal canals.
Fig. 10. First set of megalospheric chambers; × 320.
Fig. 11. First chambers of microspheric individual; × 320.
Fig. 12. Ventral view of canadabalsam-preparation, showing the first coils of the spiral canal; × 125.



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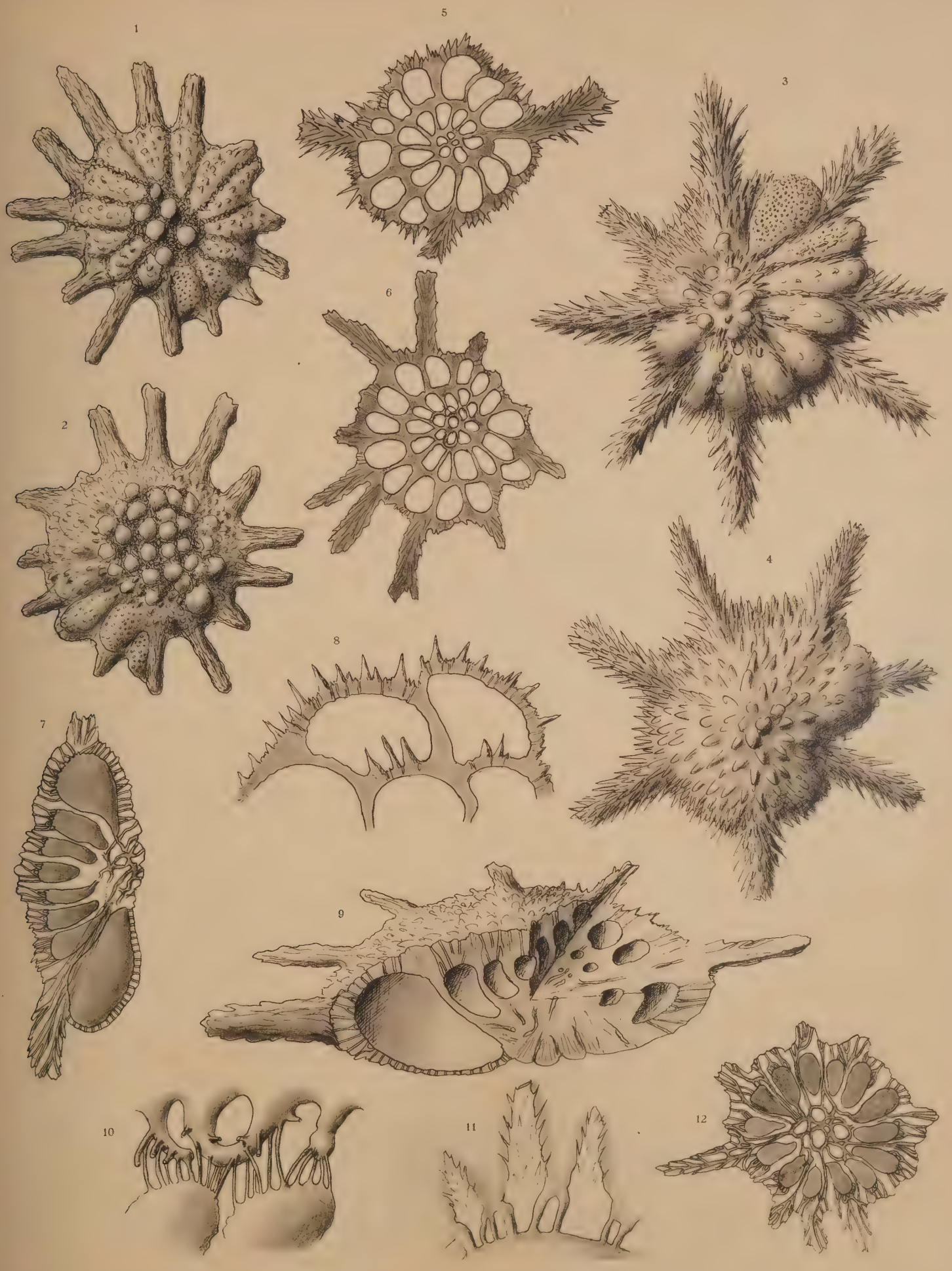
ROTALIA SCHROETERIANA.

PLATE XX.

Calcarina mayori.

Figs. 1 and 2. Ventral and dorsal sides of the typical form; × 38.
Figs. 3 and 4. Ventral and dorsal sides of the spinous type; × 60.
Fig. 5. Horizontal slide of the spinous type; × 38.
Fig. 6. Horizontal slide of the typical form; × 38.
Fig. 7. Transverse section through the typical form; canadabalsam-preparation; × 60.
Fig. 8. Part of a section of the walls of the spinous form, showing spines on the overgrown walls of chambers belonging to older rows; × 180.
Fig. 9. Schematic figure showing the arrangement of the chambers.
Fig. 10. Pores, ending on dorsal side in short canals; × 180.
Fig. 11. Canadabalsam-preparation of the wall of the chamber of a spinous shell; × 180.
Fig. 12. Canalsystem, canadabalsam-preparation; × 38.

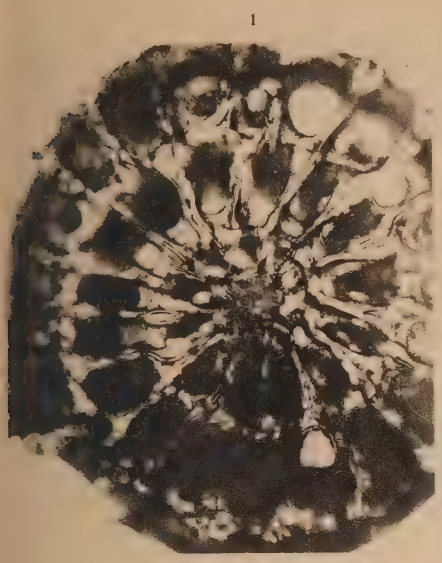


CALCARINA MAYORI.

PLATE XXI.

Rotalia, Calcarina.

Fig. 1. Canadabalsam-preparation of *R. schroeteriana*, forma B, with canalsystem; × 38.
Fig. 2. Canadabalsam-preparation of *R. schroeteriana*, showing bifurcation of the interseptal canals; × 60.
Fig. 3. Canadabalsam-preparation of *C. Spengleri*, showing umbilical system and lobes of the chambers communicating with this system; × 90.
Fig. 4. Transverse section of decalcified *C. Spengleri*, with some wild-growing chambers, filled up with chromatic material, described first by CARPENTER (1862, Textfig. XXXVI); × 225.
Fig. 5. Horizontal section through *C. Spengleri*, showing canalsystem; × 90.
Fig. 6. Another section of the same specimen, showing first chambers and nucleus in the second chamber; × 90.
Fig. 7. Canadabalsam-preparation of *R. schroeteriana*, forma A_1, with umbilical canalsystem; × 38.
Fig. 8. *C. Spengleri* (first two rows and two individuals of the third row) and third row with 4 specimens of *C. mayori*; × 4.
Fig. 9. Same individual as fig. 7, not so highly magnified (× 50), showing a spine.
Fig. 10. Section through equitant chambers of *C. Spengleri*; × 55.
Fig. 11. Transverse section of canadabalsam-prep. of *R. schroeteriana*; × 38.
Fig. 12. *C. mayori*; × 60.
Fig. 13. Canadabalsam-preparation of megalospheric specimen of *R. schroeteriana*, showing canalsystem; × 60.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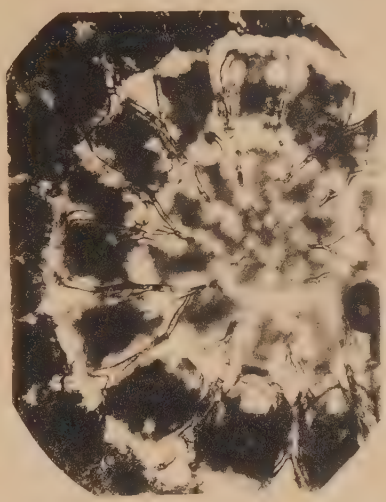
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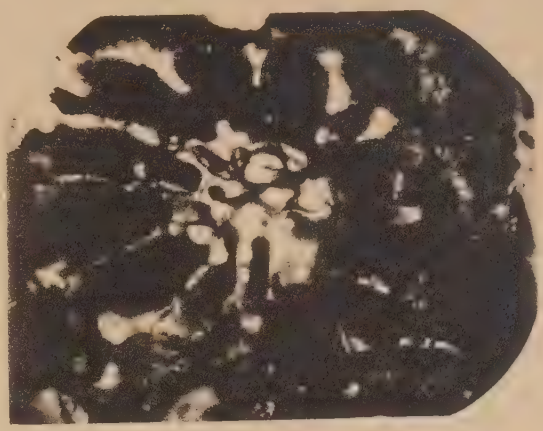
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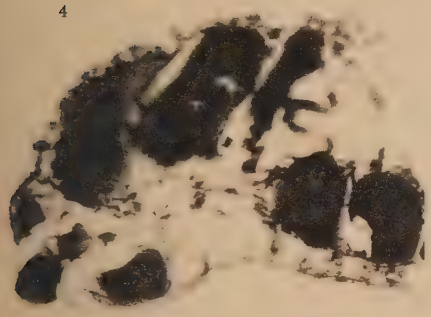
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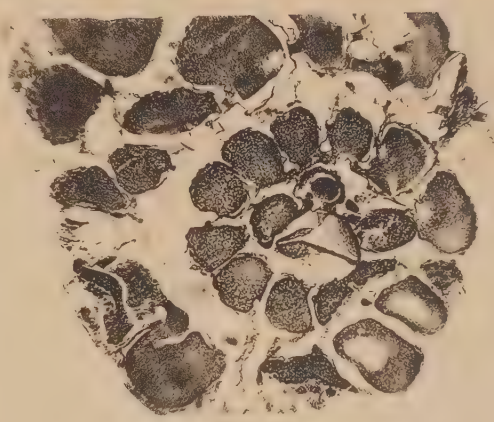
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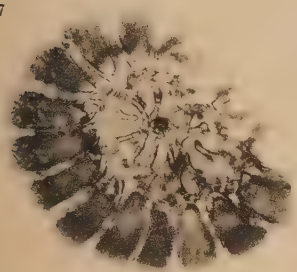
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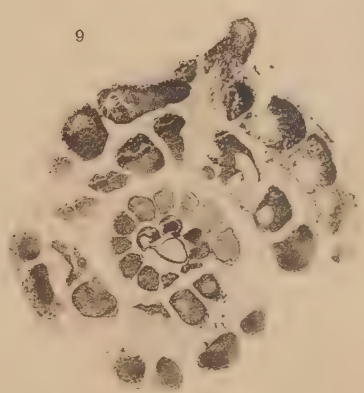
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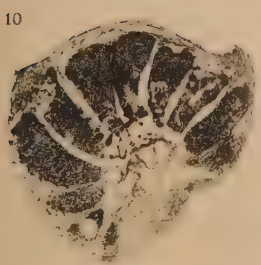
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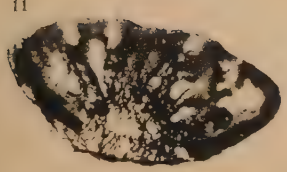
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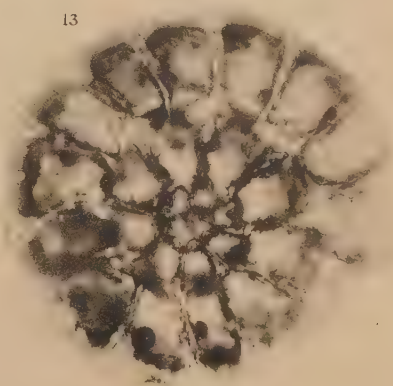
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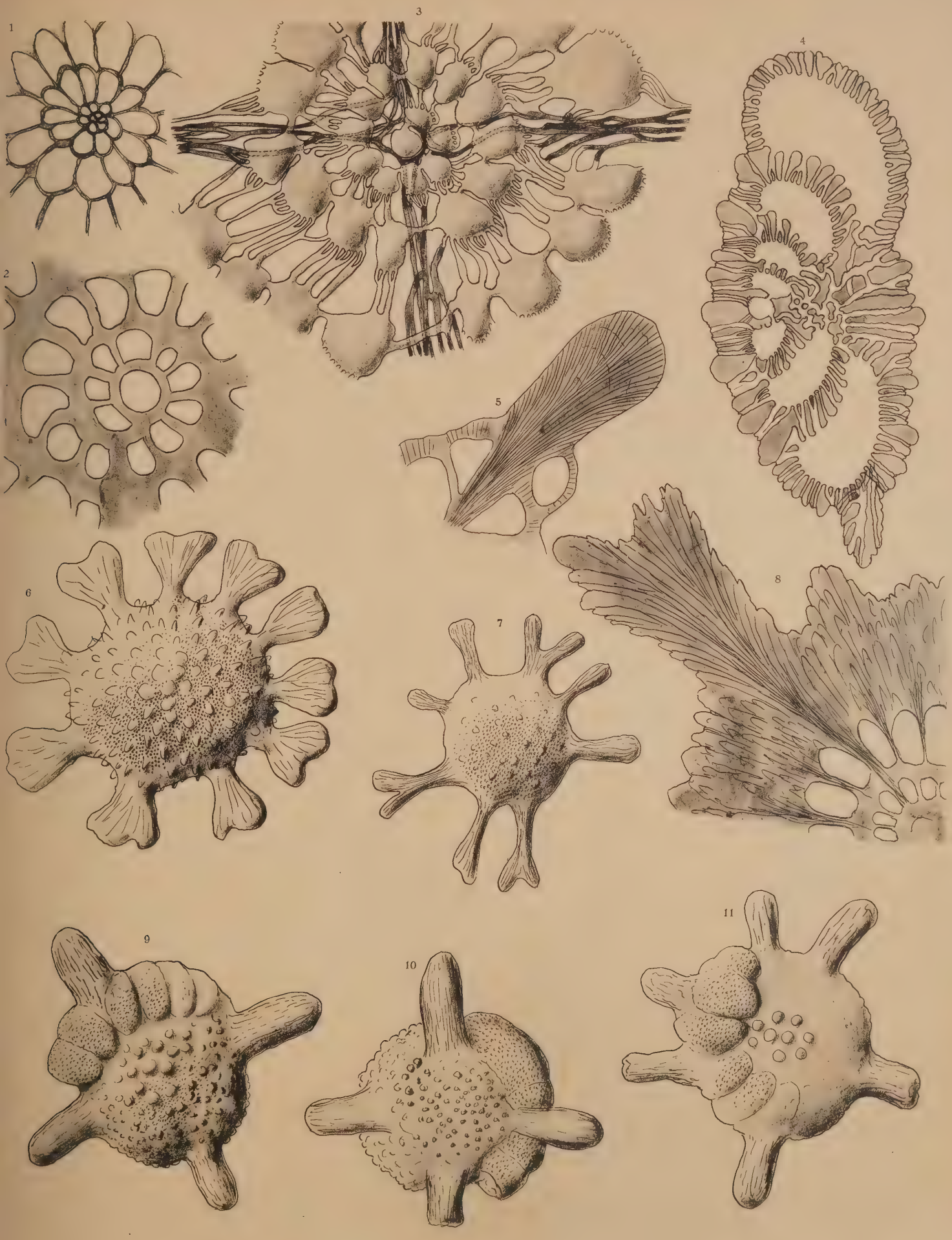
ROTALIA; CALCARINA.

PLATE XXII.

Calcarina Spengleri.

Fig. 1. Central portion of a slide of a microspheric specimen, schematical; × 90.
Fig. 2. Central part of a megalospheric specimen; × 90.
Fig. 3. Canadabalsam-preparation of a megalospheric individual, showing the canalsystem (dark coloured) and the canals in which the pores end. Four skeins of canals form the system of the spines; × 95.
Fig. 4. Transverse section through a shell of megalospheric *Calcarina*; × 60.
Fig. 5. Section through a spine of megalospheric shell; × 105.
Fig. 6. Microspheric, fullgrown specimen; × 30.
Fig. 7. Younger microspheric individual; × 30.
Fig. 8. Section through a spine of microspheric shell; × 105.
Fig. 9. Forma A_2, ventral side; × 30.
Fig. 10. Forma A_2, dorsal side; × 30.
Fig. 11. Forma A_1, ventral side; × 30.

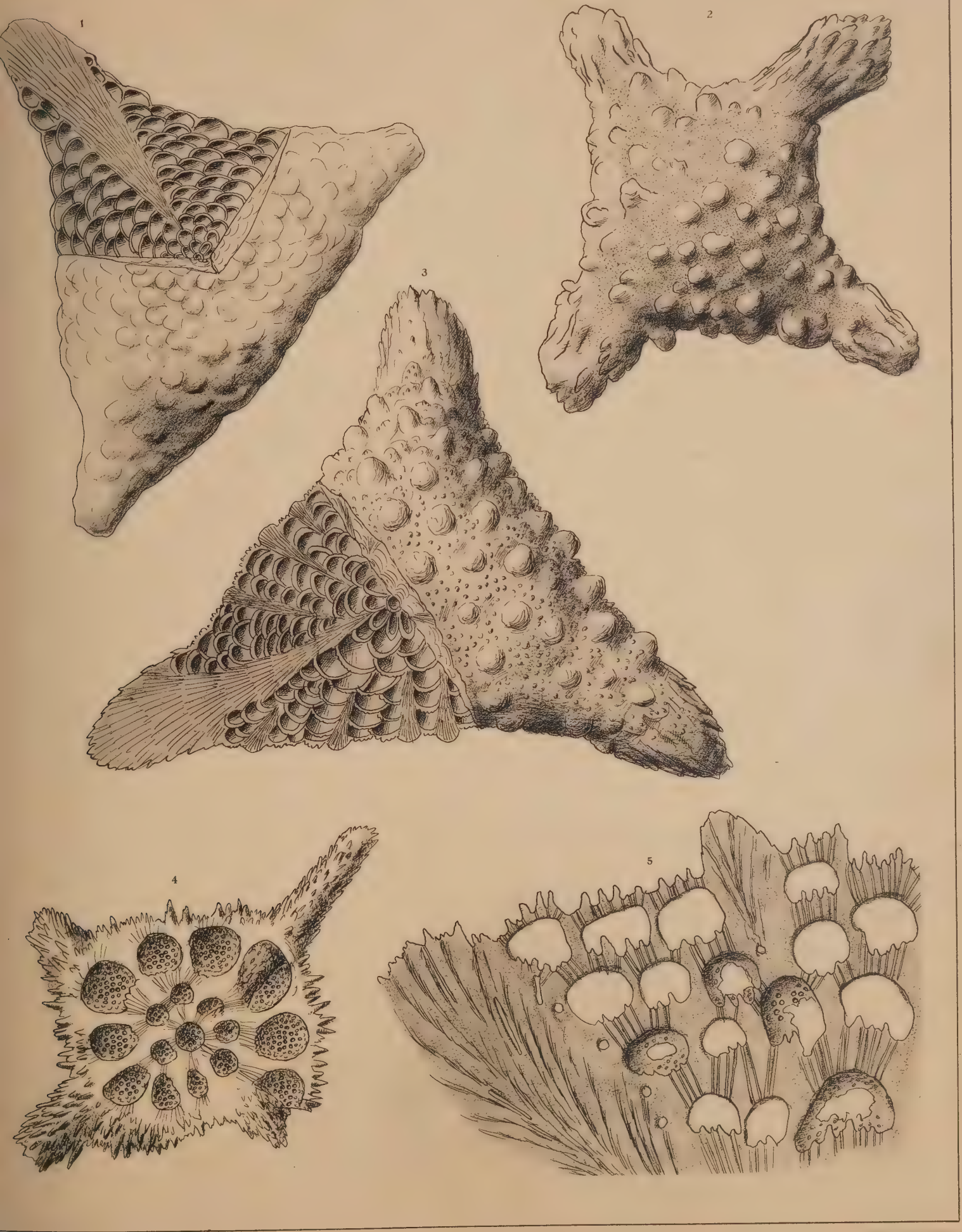


CALCARINA SPENGLERI.

PLATE XXIII.

Baculogypsina tetraëdra.

Fig. 1. Megalospheric specimen without columns, forma A_2; × 24.
Fig. 2. Microspheric individual; × 24.
Fig. 3. Megalospheric form (forma A_1), with well developed chambers; × 24.
In figs. 1 and 3 part of the shell is taken away, to show the inner structure.
Fig. 4. Young specimen of megalospheric form, the upper parts of the shell taken away, showing first spiral and beginning of a spine at the first coil; × 60.
Fig. 5. Chambers of a shell of forma A_2, showing a spine and canals; × 60.



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BACULOGYPSINA TETRAËDRA.

PLATE XXIV.

Baculogypsina and *Cycloclypeus.*

Fig. 1. Section through the centre of *Cycloclypeus carpenteri*, microspheric form; × 20.
Fig. 2. Slide through a specimen of forma A_1 of *B. tetraëdra*; × 30.
Fig. 3. Canadabalsam-preparation of a slide through the spine of forma A_2, showing canals; × 180. *B. tetraëdra.*
Fig. 4. Slide through the dorsal (*a*) and two of the horizontal spines (*b* and *c*) of forma A_2; canadabalsam-preparation, showing in the middle the umbilical canalsystem; × 60. *B. tetraëdra.*
Fig. 5. Transverse slide through forma A_1; × 30. *B. tetraëdra.*
Fig. 6. Canadabalsam-preparation of forma A_2, showing the whole slide; × 30. *B. tetraëdra.*
Fig. 7. Slide through young megalospheric specimen; × 24. *B. tetraëdra.*
Fig. 8. Forma A_2 of *B. sphaerulata*; slide; × 24; very irregular.
Fig. 9. Slide through microspheric specimen of *B. tetraëdra*; × 24.
Fig. 10. Slide through regular specimen of *B. sphaerulata*, with columns; × 36.
Fig. 11. Transverse section through decalcified specimen of megalospheric *B. sphaerulata*, showing thick walls of first spiral of chambers; × 60.
Fig. 12. Young megalospheric *B. sphaerulata*; × 60.
Fig. 13. Decalcified specimen of *B. sphaerulata*, showing columns; × 36.
Fig. 14. Whole individual of *B. sphaerulata*, with spines covered by chambers; × 30.
Fig. 15. *B. sphaerulata*, young, showing the first irregular chambers, growing against the spines; × 75.

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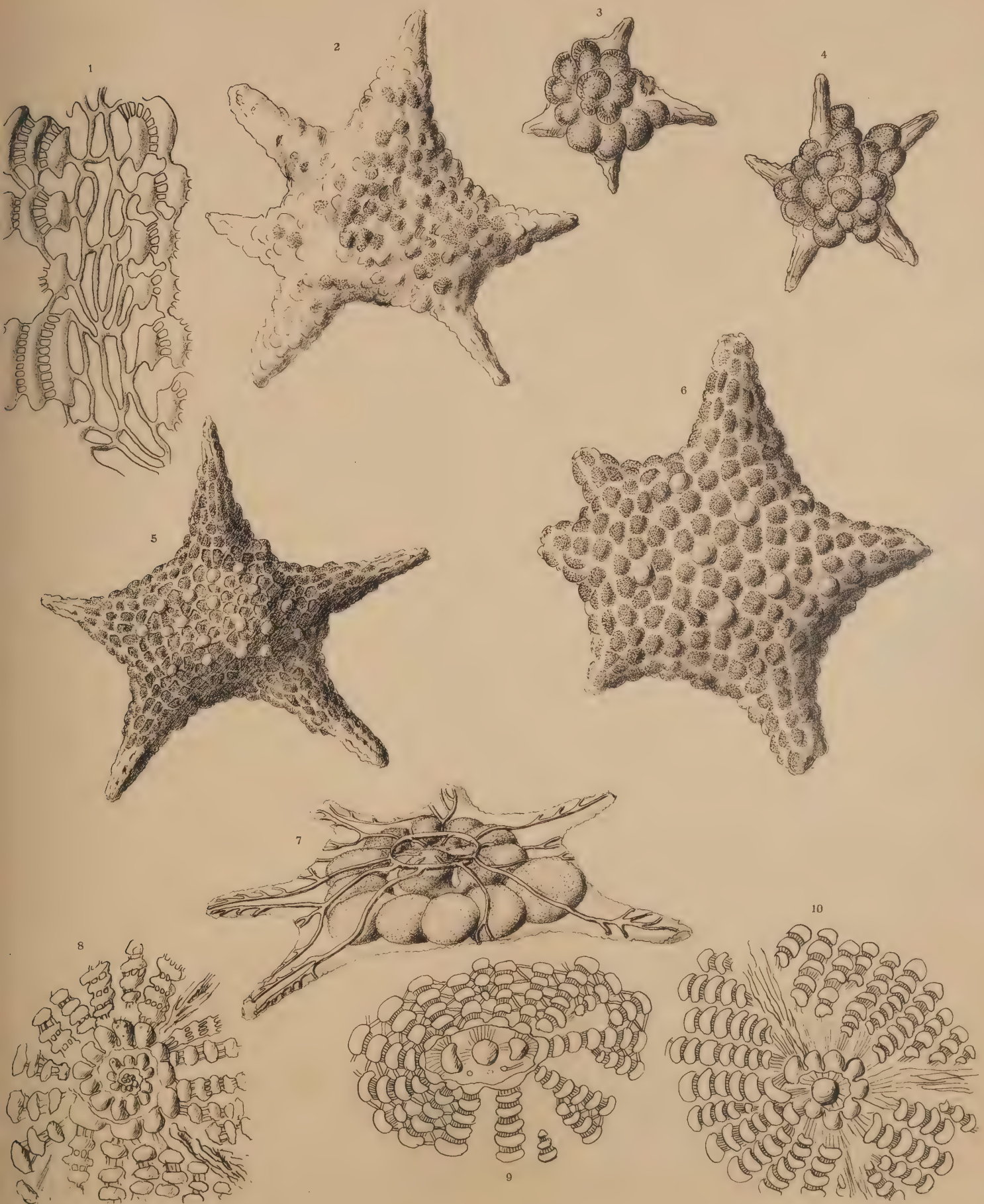
BACULOGYPSINA AND CYCLOCLYPEUS.

PLATE XXV.

Baculogypsina sphaerulata.

Fig. 1. Canalsystem in a spine, with adjacent chambers, canadabalsam-preparation; × 380.
Fig. 2. Megalospheric individual, forma A_1; × 60.
Fig. 3. Young megalospheric specimen; × 125.
Fig. 4. Young megalospheric specimen, somewhat older; × 125.
Fig. 5. Megalospheric specimen, forma A_2; × 60.
Fig. 6. Microspheric form; × 75.
Fig. 7. Schematic figure, showing the canalsystem on the ventral side; × ± 380.
Fig. 8. Section through microspheric specimen; × 60.
Fig. 9. Transverse section through megalospheric individual, showing thick walls of the first convolutions; × 60.
Fig. 10. Horizontal section through megalospheric specimen; × 60.



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BACULOGYPSINA SPHAERULATA.

PLATE XXVI.

Nonionina and *Polystomella*, canadabalsam-preparations; chambers yellow; canalsystem brownish.

Fig. 1. *Nonionina asterizans*, transverse section; × 105.
Fig. 2. *Nonionina asterizans*, horizontal section, showing spiral-canal; section not exactly through central chamber; × 105.
Fig. 3. Transverse section through *Polystomella striato-punctata*; × 105.
Fig. 4. Single chamber of the same, showing retral processes, meridional canal of the foregoing coil, and the canal belonging to this chamber, ramifying into the short canals between the retral processes; × 105.
Fig. 5. *Pol. macella*, showing canalsystem; × 105.
Fig. 6. *Pol. macella*, canalsystem and foramina; × 105.
Fig. 7. Openings of canalsystem at the sutures of *Pol. striato-punctata*; × ± 300.
Fig. 8. Transverse section through *P. crispa*; × 105.
Fig. 9. Openings of canalsystem, *P. macella*; × 300.
Fig. 10. Schematic figure of the peripheral canalsystem of *P. craticulata*, micro- and megalospheric forms combined into one figure; × 105.
Fig. 11. Transverse section through *P. craticulata*; × 105.
Fig. 12. Openings of canalsystem, *P. craticulata*, megalospheric; × ± 300.
Fig. 13. Openings of canalsystem, *P. craticulata*, microspheric; × ± 300.
Fig. 14. Fan-shaped "forking" canals, *P. craticulata*; × ± 300.
Fig. 15. Forking canals, microspheric, *P. craticulata*; × ± 300.

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NONIONINA, POLYSTOMELLA.

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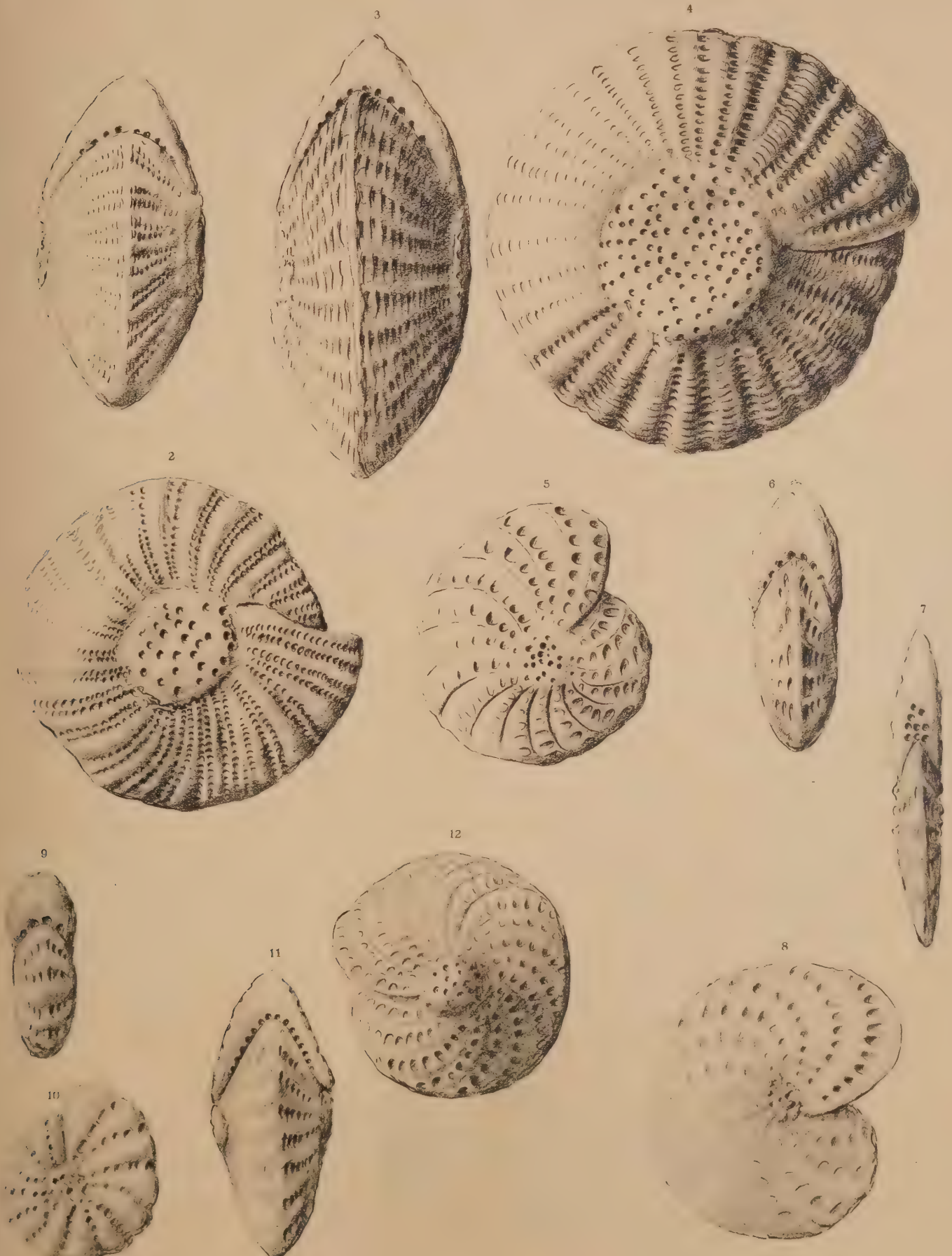
PLATE XXVII.

Polystomella.

Figs. 1 and 2. *P. craticulata,* young microspheric individual; × 60.
Figs. 3 and 4. *P. craticulata,* megalospheric specimen; × 60.
Figs. 5 and 6. *P. crispa,* megalospheric young specimen; × 60.
Figs. 7 and 8. *P. "macella"*; × 60.
Figs. 9 and 10. *P. striato-punctata*; megalospheric specimen; × 60.
Figs. 11 and 12. *P. crispa,* microspheric individual; × 60.



POLYSTOMELLA.

PLATE XXVIII.

Polystomella.

Fig. 1. *P.* "*macella*", showing pores and openings of canals; × 150.
Fig. 2. *P.* "*macella*", idem.
Fig. 3. Transverse section through *P. crispa*, × 180, showing interseptal canals, retral processes and foramina.
Fig. 4. Microspheric specimen of *P. craticulata*, canadabalsam-preparation; × 38.
Fig. 5. Microspheric specimen of *P. crispa*; × 38.
Fig. 6. Megalospheric specimen of *P. crispa*; × 40.
Fig. 7. First coils of spiral-canal of *P. crispa*; × 90.
Fig. 8. Transverse section through *P. craticulata*, showing umbilical canals; × 65.
Fig. 9. Section through *P. striato-punctata*; × 185.
Fig. 10. Spiral-canal of *P. craticulata*; × 90.
Fig. 11. Canadabalsam-preparation of *P. craticulata*, microspheric individual, showing forking canals; × 48.
Fig. 12. Section through *P. crispa*, megalospheric; × 80.

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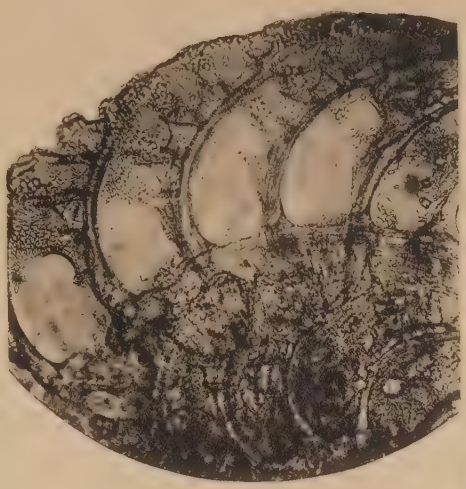
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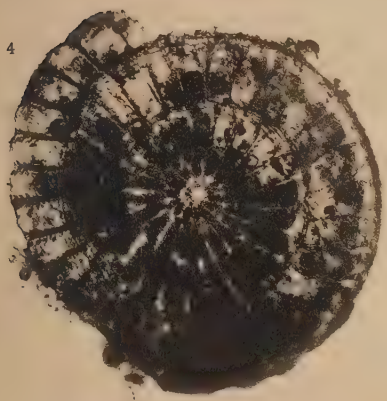
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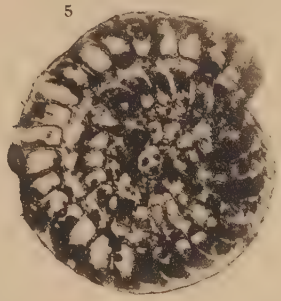
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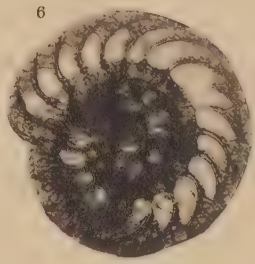
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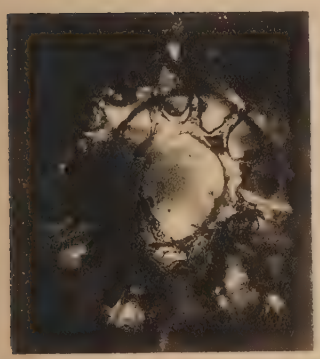
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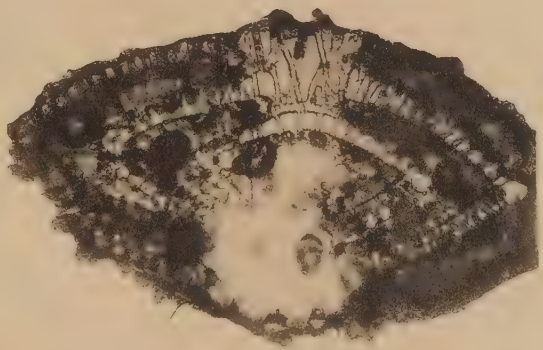
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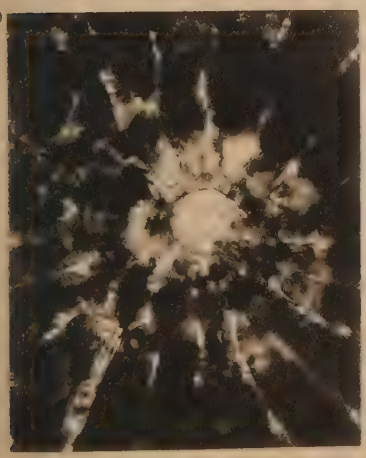
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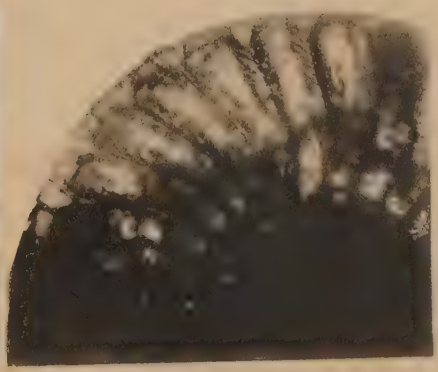
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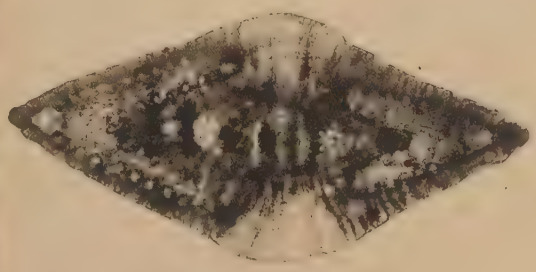
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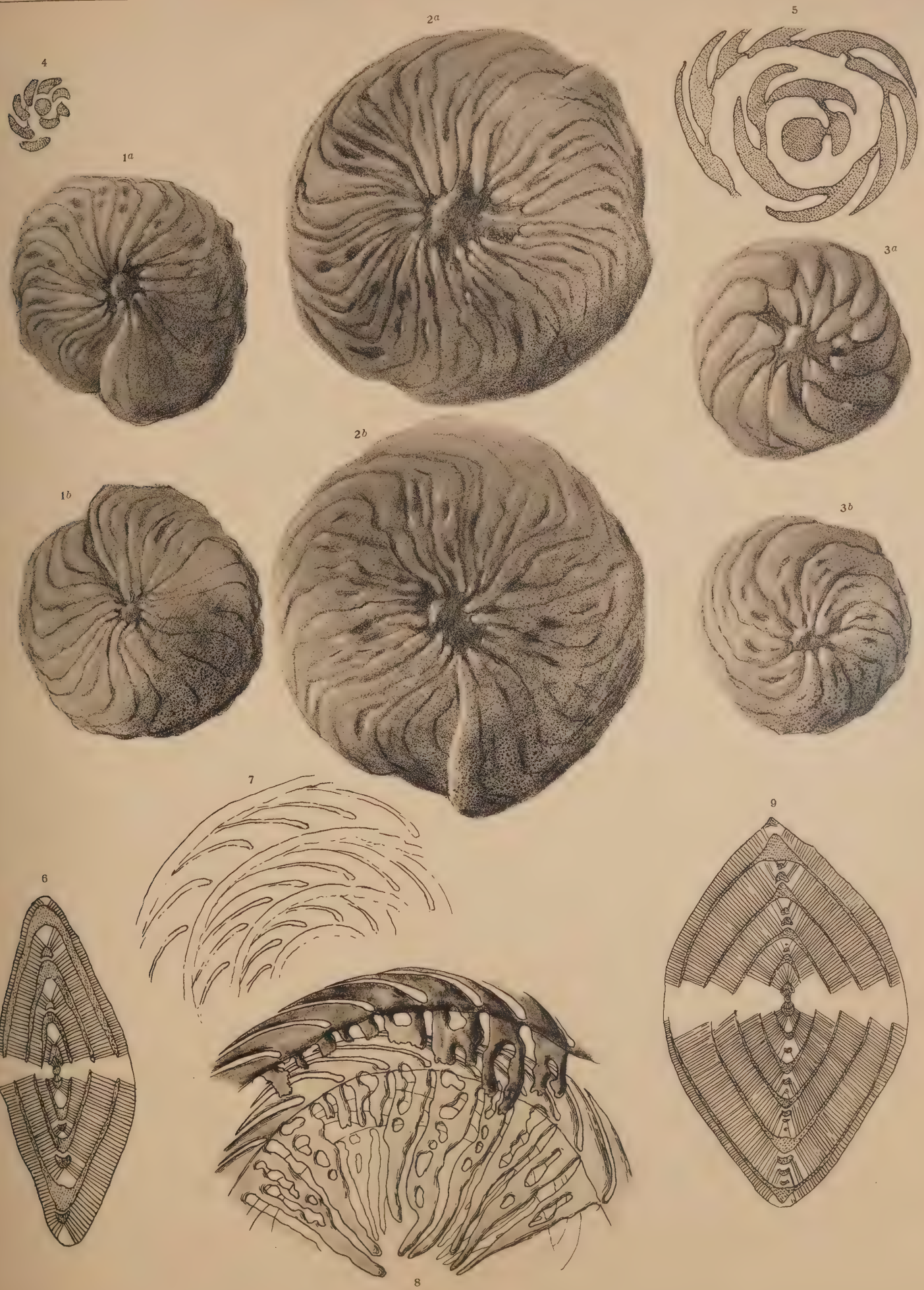
OFKER PHOT

POLYSTOMELLA.

PLATE XXIX.

Amphistegina radiata.

Fig. 1, *a* and *b*. Megalospheric specimen, forma A_1, both sides; × 25.
Fig. 2, *a* and *b*. Microspheric specimen, forma B; × 25.
Fig. 3, *a* and *b*. Megalospheric specimen, forma A_2; both sides. × 25.
Fig. 4. First chambers of forma B; × 290.
Fig. 5. First chambers of forma A_2; × 60.
Fig. 6. Transverse section of a megalospheric shell; between the sections of whole chambers with their alar prolongations are seen the retral processes of other chambers; × 50.
Fig. 7. Horizontal section of microspheric specimen; × 60.
Fig. 8. Canadabalsam-preparation of some outer convolutions of microspheric form; × 45.
Fig. 9. Transverse section of a microspheric specimen; × 25.



AMPHISTEGINA RADIATA.

PLATE XXX.

Amphistegina, Polytrema album, Planorbulina, Operculina.

Fig. 1. *Polytrema album*, decalcified specimen, on sponge; × 60.
Fig. 2. *Amphistegina radiata*, horizontal section, decalcified canadabalsam-preparation, megalospheric specimen; × 120.
Fig. 3. *Amphistegina radiata*, transverse section through microspheric specimen; × 55.
Fig. 4. *Amphistegina radiata*, megalospheric, transverse section; × 50.
Fig. 5. *Operculina complanata*, decalcified canadabalsam-preparation, showing the fine pores in the wall; × 300.
Fig. 6. *Amphistegina radiata*, horizontal section through microspheric specimen, showing whole chambers of two outer convolutions; × 40.
Fig. 7. *Amphistegina radiata*, some megalospheric individuals; × 3.
Fig. 8. *Polytrema album*, attached to some weed; × 4,5.
Fig. 9. *Polytrema album*, section through a colony with two mouths, in which sponge-spicules are visible; × 36.
Fig. 10. *Planorbulina larvata*, section showing chamberwalls, the pores and foramina; × 45.
Fig. 11. *Planorbulina larvata*, decalcified canadabalsam-preparation; × 75.
Fig. 12. Complete specimen of *Planorbulina larvata*, forma A_1; × 30.

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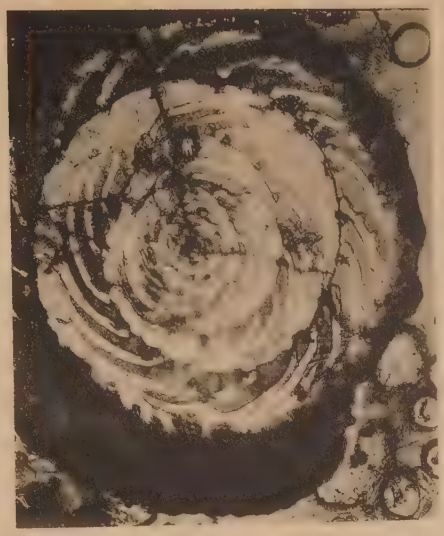
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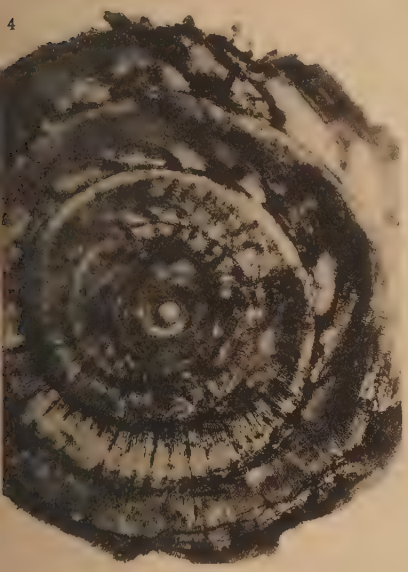
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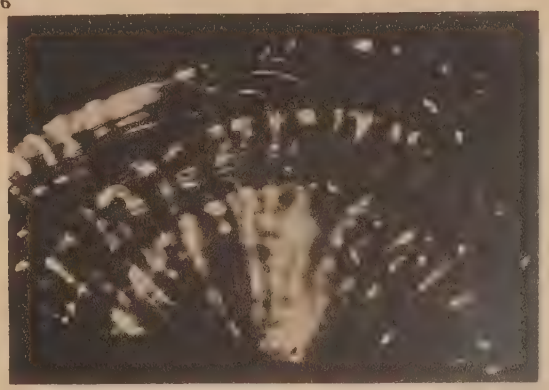
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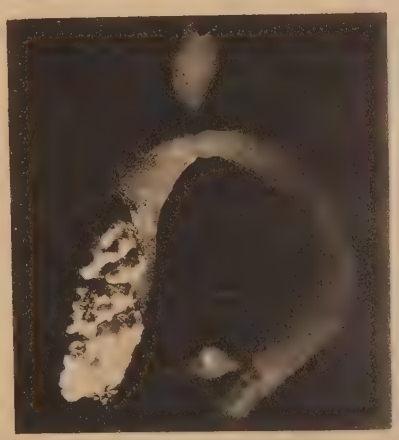
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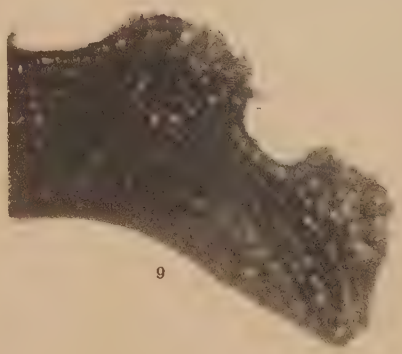
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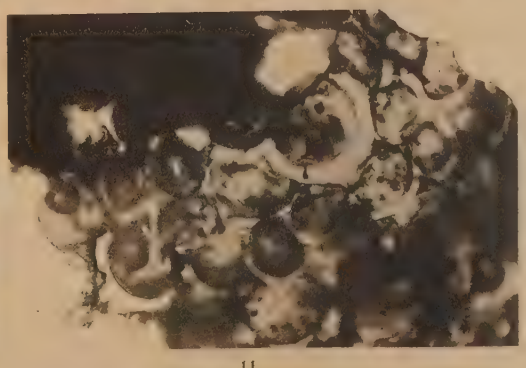
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AMPHISTEGINA, POLYTREMA ALBUM, PLANORBULINA, OPERCULINA.

PLATE XXXI.

Operculina complanata.

Fig. 1. *a*, microspheric form; × 13.
b, surface of the shell, showing pores and beads of chalk; × 375.
c, first chambers of the same form; × 300.
d, transverse section through part of the shell; × 375.

Fig. 2. *a*, megalospheric specimen with small first chamber, showing typical features of forma A_1; × 13.
b, surface of the shell; × 375.
c, first chambers; × 300.

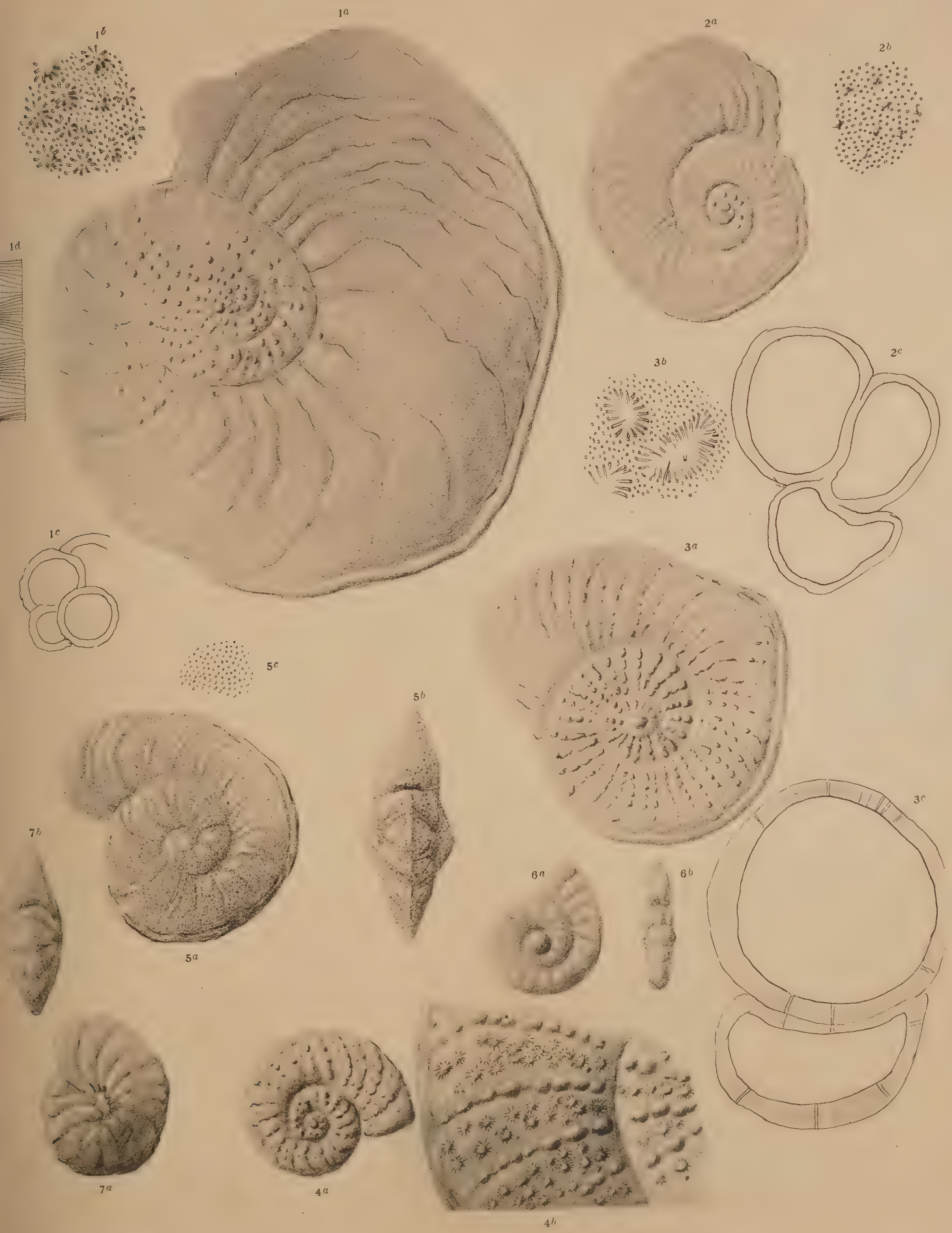
Fig. 3. *a*, megalospheric specimen with large proloculum; × 13.
b, surface of part of the shell; × 375.
c, first chambers; × 300.

Fig. 4. *a*, specimen with very well developed secondary chalk; × 13.
b, same specimen, part of the shell; × 25.

Fig. 5. *a* and *b*, specimen with more broadened chambers; × 13.
c, part of the surface, with pores; × 375.

Fig. 6. *a* and *b*, a specimen from a sample of 200 fathoms' depth, showing the characteristics of *O. ammonoides*; × 13.

Fig. 7. *a* and *b*, *O. venosa*; × 13.



OPERCULINA COMPLANATA.

PLATE XXXII.

Operculina and *Heterostegina*.

Fig. 1. Microspheric individual of *H. operculinoides*; × 60.
Fig. 2. Canals of the marginal cord and interseptal ones, running into each other; canadabalsam-preparation of *O. complanata*; × 225.
Fig. 3. Surface of the shell in transmitted light of microspheric *Operculina*; × 140.
Fig. 4. Transverse section of *Operculina*, showing above the furrow at the margin of the chamber in which the marginal cord lies; × 120; canadab.-prep.
Fig. 5. Megalospheric specimen of *O. complanata* with large proloculum, showing structure of the shell; × 22.
Fig. 6. Margin of a transverse section through *Operculina*, showing the fanshaped structure surrounding the canals of the marginal cord; × 140.
Fig. 7. Interseptal canals in a septum of *Operculina*; canadab.-prep.; × 140.
Fig. 8. The same section as fig. 6, but a canadab.-prep., showing canals of marginal cord, of spiral system and of the septum, and the furrow at the margin of the chambers; × 140.
Fig. 9. Canals of the marginal cord of *Operculina*; canadab.-prep.; × 140.
Fig. 10. *H. operculinoides*, showing the canals in the walls of the chamberlets; canadab.-prep.; × 180; microspheric specimen.
Fig. 11. *H. operculinoides*; idem.
Fig. 12. Megalospheric specimen of *H. operculinoides*, showing canalsystem of the first convolutions; × 130; canadab.-prep.

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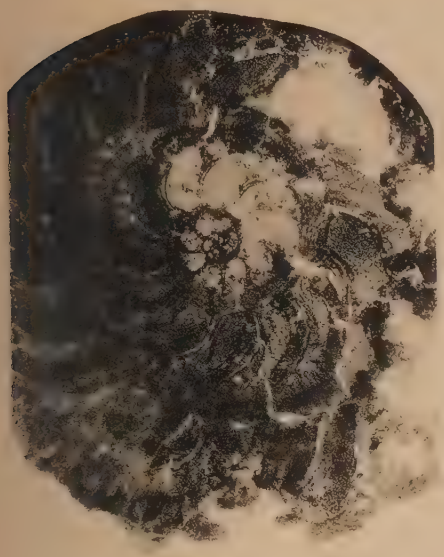

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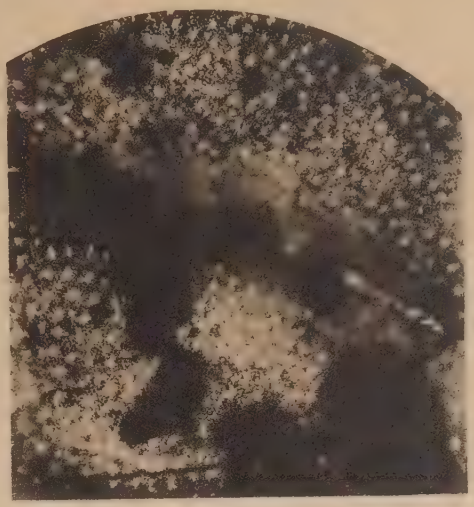

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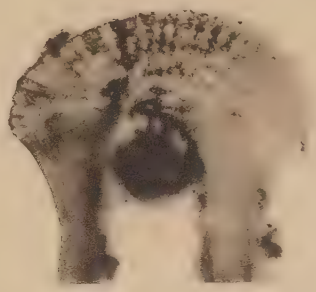

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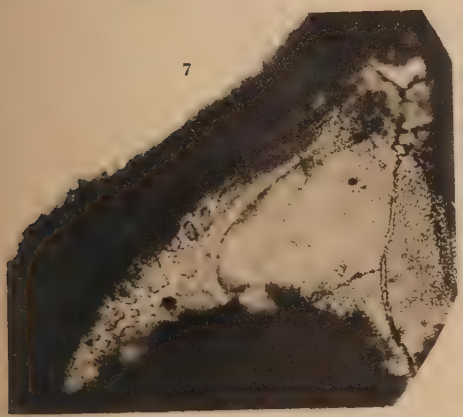

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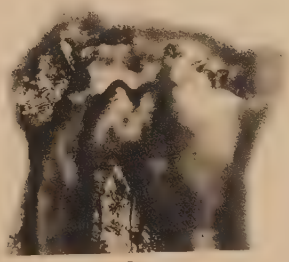

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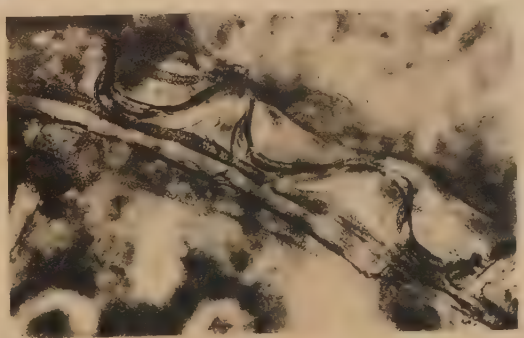

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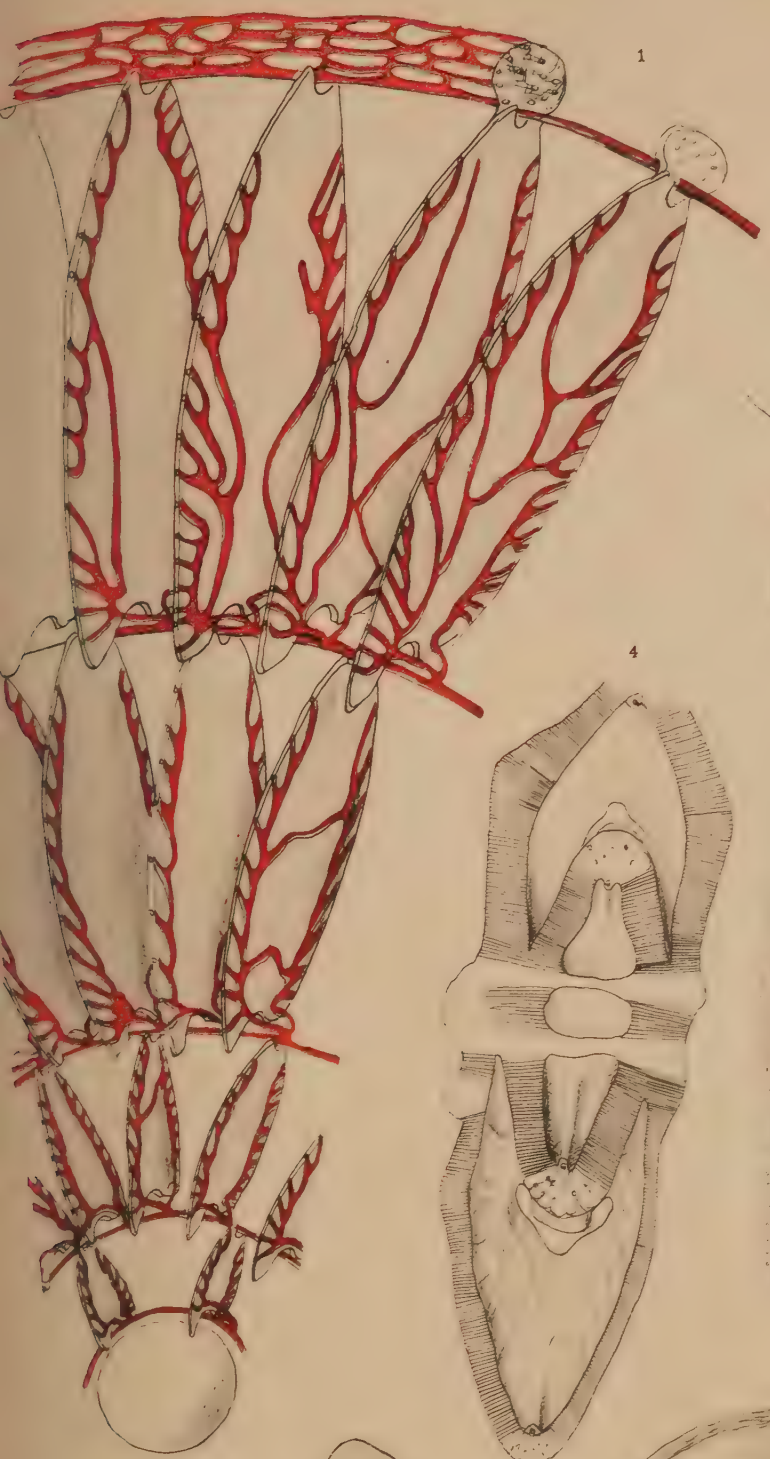
HOFKER, PHOT.

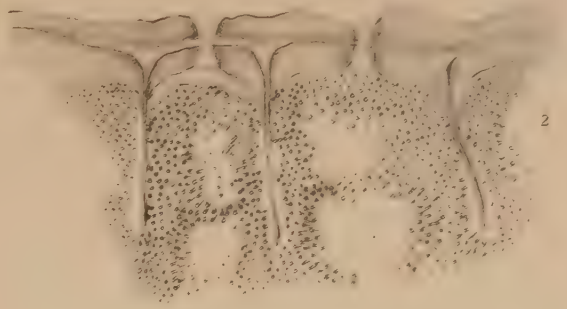
OPERCULINA, HETEROSTEGINA.

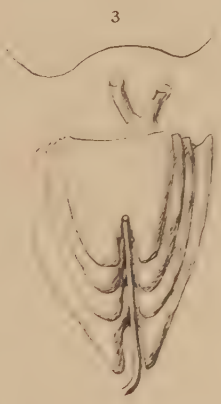
PLATE XXXIII.

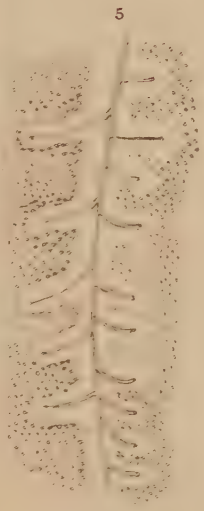
Operculina complanata.

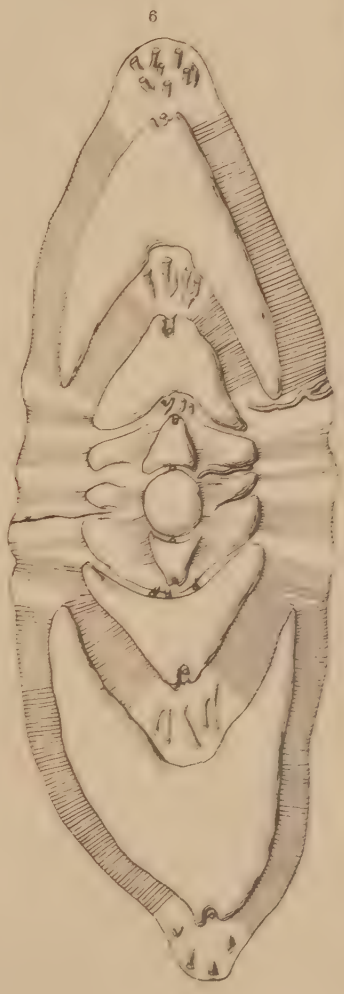
Fig. 1. Schematic figure of the canalsystem.
Fig. 2. Surface of the shell, showing the direction of the pores at the chalk-buds, and the canals at the margin; × 350.
Fig. 3. Canadabalsam-prep. of four chambers with the marginal cord-canal; × 280.
Fig. 4. Transverse section through a specimen with equitant chambers, showing canals through the chamberwalls, marginal cord and foramina; × 55.
Fig. 5. Suture with sutural canalsystem, showing the little canals running to the surface; × 350.
Fig. 6. Section through canadabalsam-prep., showing marginal cord, "spiral" canals and umbilical canals; × 55.
Fig. 7. Section through complanate specimen; × 55.
Fig. 8. Megalospheric first coils of chambers, with beginning of marginal cord; × 200.
Fig. 9. Specimen of forma A_1, but with largely developed secondary chalk substance; × 25.
Fig. 10. Margin of the section of fig. 7, showing the structure of the marginal cord; × 150.

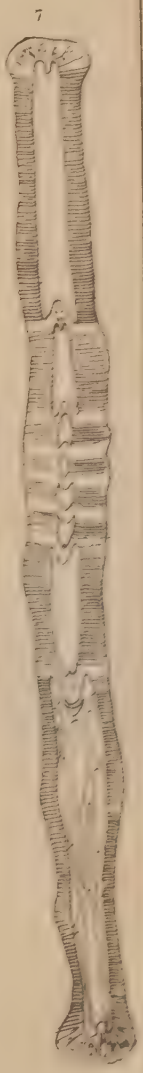


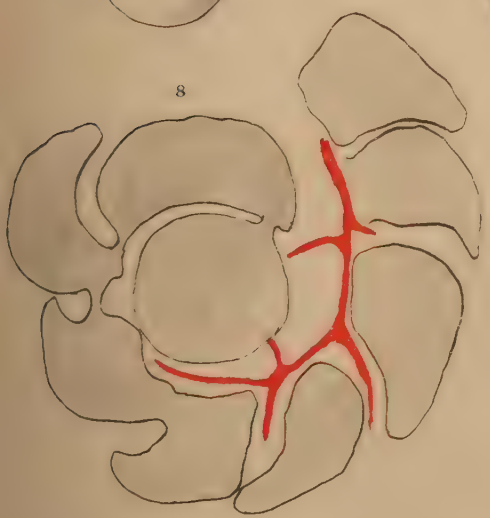


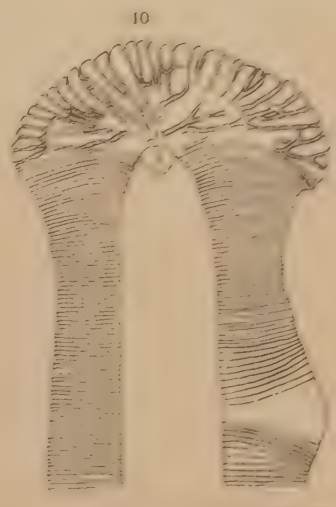










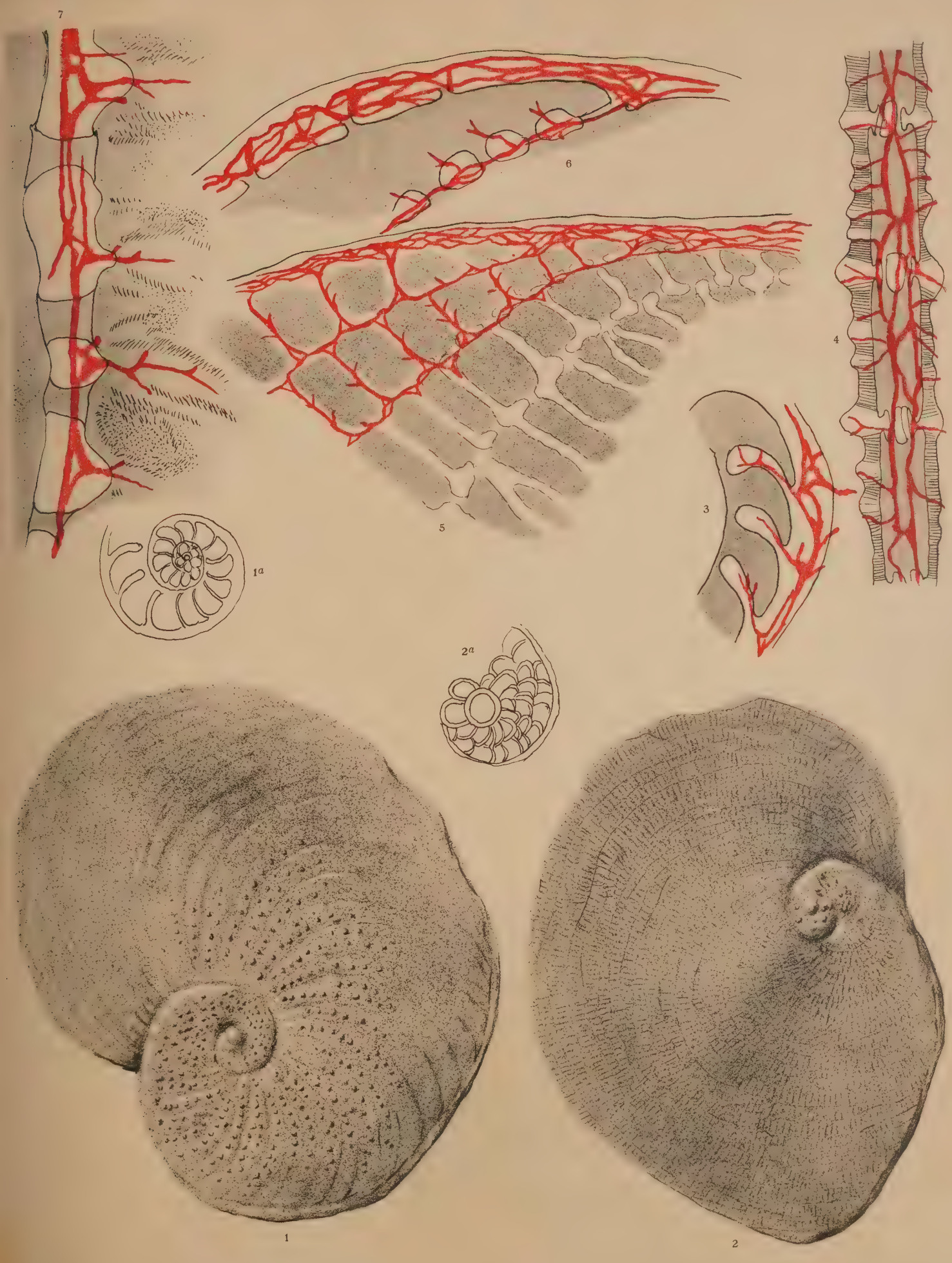


OPERCULINA COMPLANATA.

PLATE XXXIV.

Heterostegina operculinoides.

Fig. 1. Microspheric specimen; × 13. Fig. 1*a*. Section through the centre; × 25.
Fig. 2. Megalospheric individual, × 13. Fig. 2*a*. Section through the centre; × 25.
Fig. 3. One of the first convolutions of the microspheric form, with its canalsystem; × 180.
Fig. 4. Transverse section through megalospheric form, with canalsystem of the secondary chamberwalls; ×180.
Fig. 5. Part of megalospheric form, with canalsystem; × 180.
Fig. 6. Part of microspheric form, with canals; × 180.
Fig. 7. Canals of a suture of microspheric form, showing sutural canals and offshoots, forming in megalospheric individuals the canals of the walls of secondary chambers; × 240.

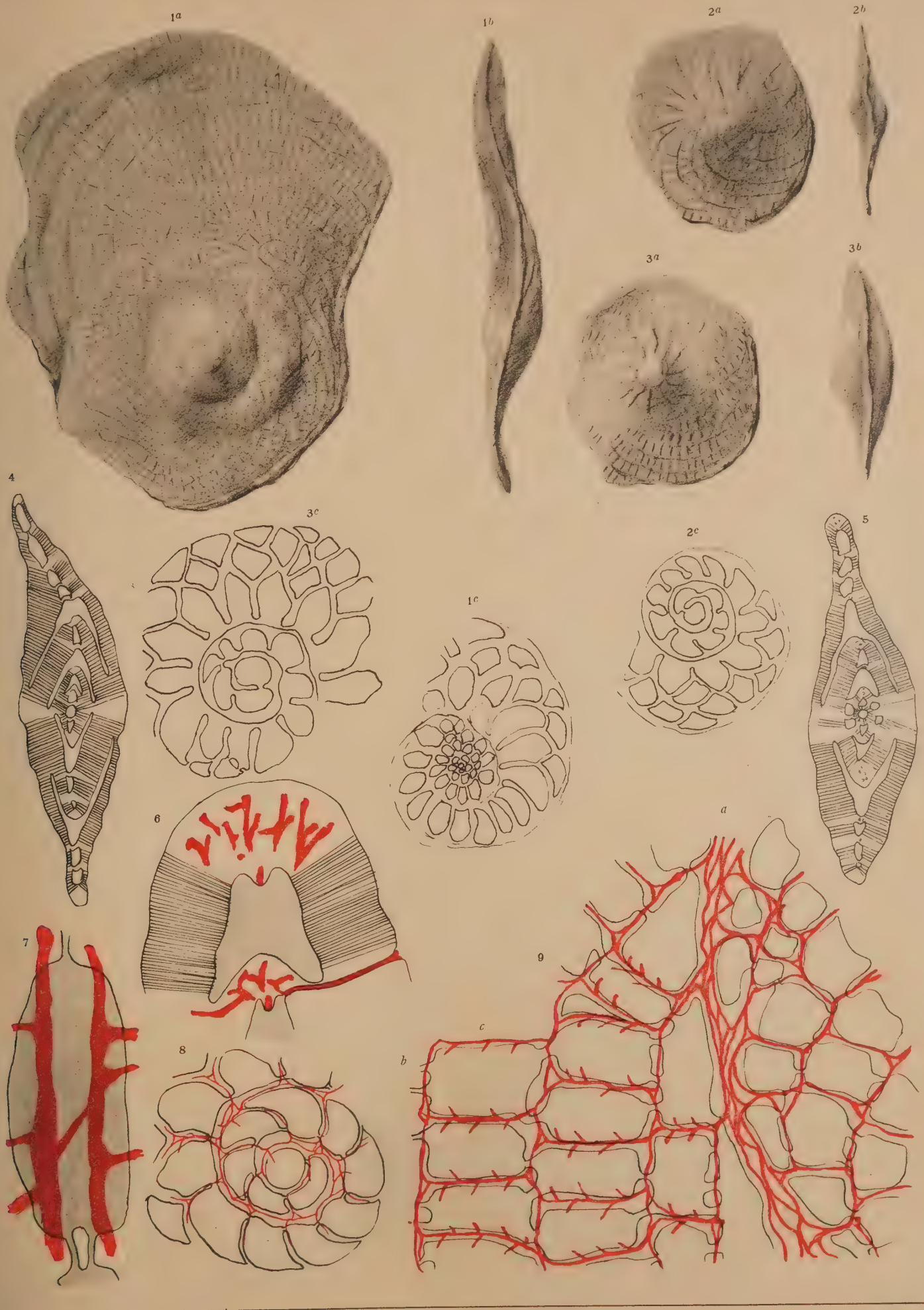


HETEROSTEGINA OPERCULINOIDES.

PLATE XXXV.

Heterostegina suborbicularis.

Fig. 1. *a* and *b*. Microspheric specimen; × 6.5; 1*c* schematic section through centre of shell; × 60.
Fig. 2. *a* and *b*. Forma A_1 of megalospheric form; × 6.5; 2*c* schematic section through centre of shell; × 60.
Fig. 3. *a* and *b*. Forma A_2 of megalospheric form; × 6.5; 3*c* schematic section through centre of shell; × 60.
Fig. 4. Transverse section through a megalospheric specimen with large proloculum; × 30.
Fig. 5. Section through the other megalospheric form; × 30.
Fig. 6. Canalsystem on a transverse section, showing its typical nummulitical features; × 185.
Fig. 7. Canals in the secondary wall of a chamberlet; × 185.
Fig. 8. Canalsystem in a microspheric specimen; × 75.
Fig. 9. Canalsystem of part of a shell, seen in horizontal section; *a*: marginal cord; *b*: canals in the sutures of the chambers; *c*: canals in the walls of the chamberlets; × 120.

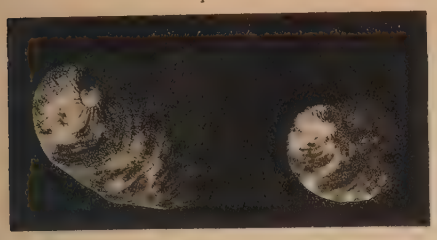


HETEROSTEGINA SUBORBICULARIS.

PLATE XXXVI.

Heterostegina.

Fig. 1. Microspheric specimens of *H. operculinoides*; × 2.5.
Fig. 2. Canals in the walls of chamberlets of *H. operculinoides*, megalospheric form; × 150 (canadab.-prep.).
Fig. 3. *H. suborbicularis*, horizontal section through a megalospheric specimen with large proloculum; × 36.
Fig. 4. *H. operculinoides*, megalospheric specimen, section; × 36.
Fig. 5. Canals of marginal cord and of the chamberwalls of *H. operculinoides*, megalospheric form; horizontal section, canadab.-prep.; × 180.
Fig. 6. Transverse section through megalospheric *H. suborbicularis*; × 20.
Fig. 7. Horizontal section through megalospheric *H. suborbicularis*, with small proloculum; × 36.
Fig. 8. Chambers of microspheric specimen of *H. suborbicularis*, canadab.-prep.; × 36.
Fig. 9. Transverse section through megalospheric *H. suborbicularis*, canadab.-prep., showing the dentation of the margin of a chamber in which the primary marginal cord-canal lies; × 150.
Fig. 10. Another section, showing the canalsystem of the marginal cord; × 150.
Fig. 11. Canals in megalospheric spec. of *H. suborbicularis*; × 180.
Fig. 12. Canals in microspheric spec. of *H. suborbicularis*; × 180.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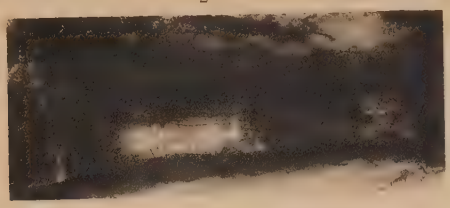
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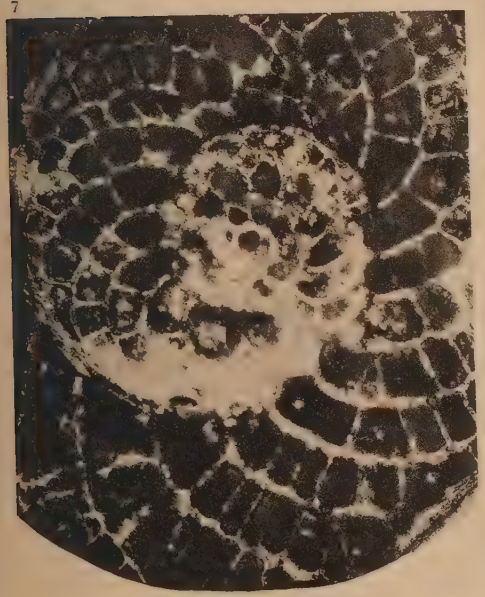
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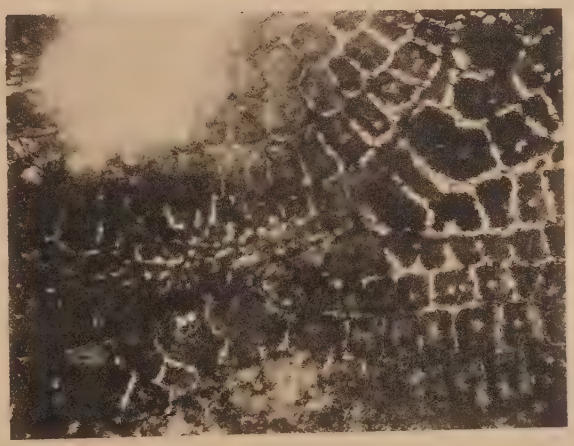
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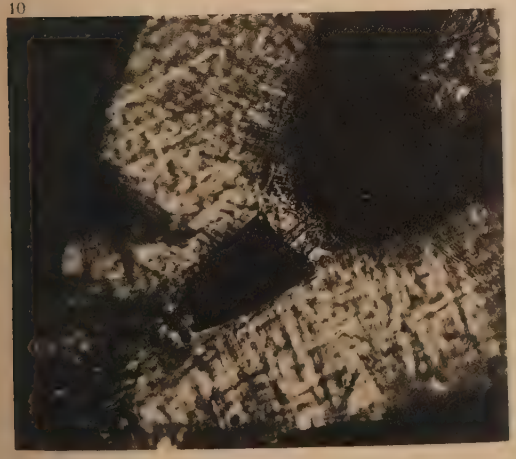
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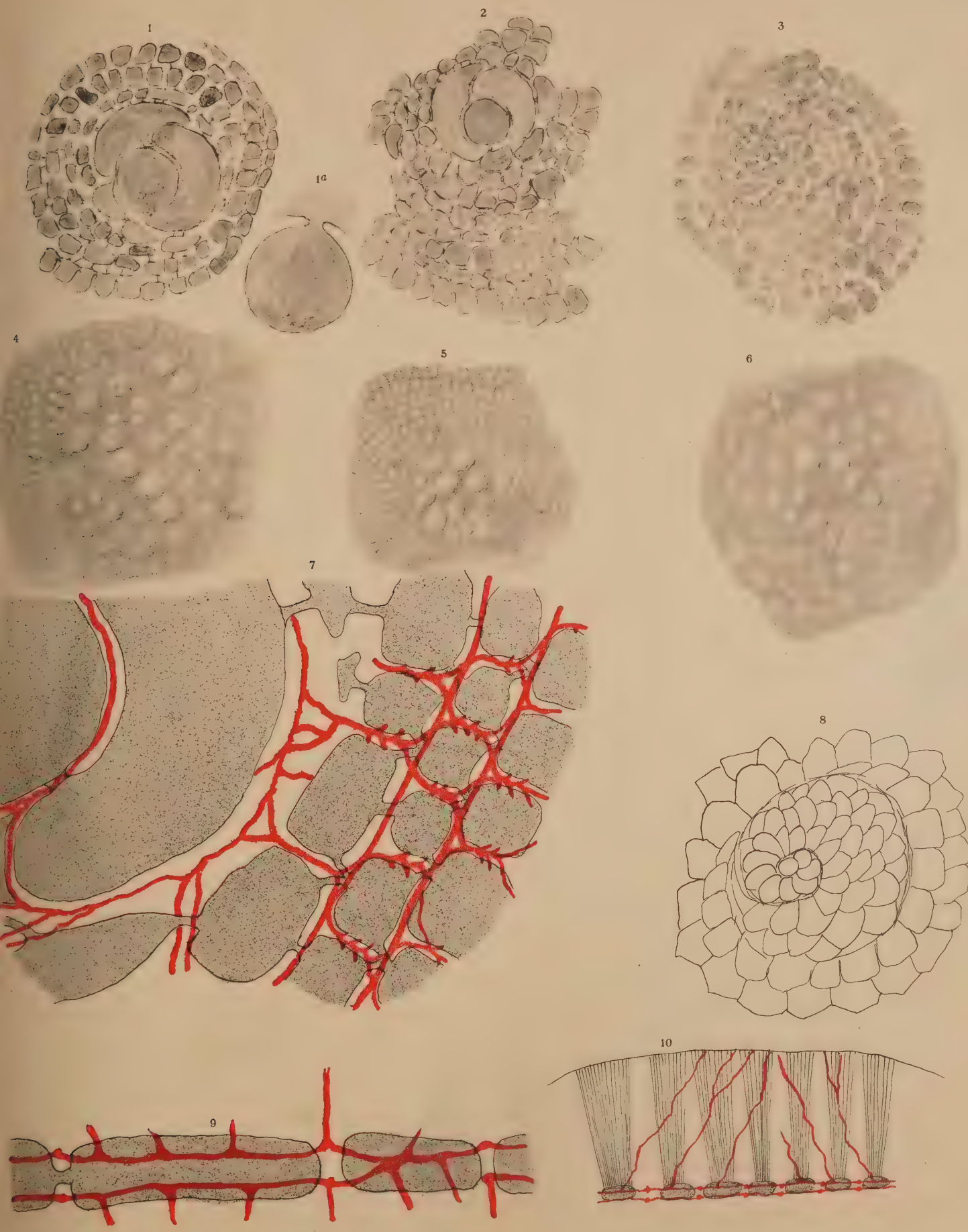
HETEROSTEGINA.

PLATE XXXVII.

Cyclŏclypeus carpenteri.

Fig. 1. Megalospheric form with large proloculum; × 45.
Fig. 1*a*. A first chamber of yet larger size; × 45.
Fig. 2. Megalospheric spec. with small proloculum; × 45.
Fig. 3. Microspheric specimen; × 45.
Fig. 4. Part of the centre of the surface of a microspheric specimen; × 30.
Fig. 5. Part of the centre of the surface of a megalospheric individual with small first chamber; × 30.
Fig. 6. Centre of the shell of a normal megalospheric specimen; × 30.
Fig. 7. Canalsystem of the central part of a megalospheric shell; × 180.
Fig. 8. Schematic figure of the central part of a section through a microspheric shell; × 60.
Fig. 9. Canals in the walls of the chamberlets; × 120.
Fig. 10. Thickened central part of the shell, with its canals running from the normal system to the surface; × 60.



CYCLOCLYPEUS CARPENTERI.

PLATE XXXVIII.

Heterostegina (figs. 10 and 11) and *Cycloclypeus*.

Fig. 1. Trivalent individual, decalcified canadab.-prep.; × 17.
Fig. 2. Specimen with five embryonic apparatus; × 17.
Fig. 3. Bivalent specimen; × 17.
Fig. 4. Normal megalospheric specimen; × 30.
Fig. 5. Very large microspheric shell; × 1.5.
Fig. 6. Normal microspheric shell; × 1.5.
Fig. 7. Trivalent specimens; × 1.5.
Fig. 8. Bivalent specimens; × 1.5.
Fig. 9. Univalent specimens; × 1.5.
Fig. 10. *Heterostegina operculinoides*, megalosph. specimens; × 2.25.
Fig. 11. Central part of the same; × 60.
Figs. 12 and 13. Young microspheric shells of *Cycloclypeus*; × 60.

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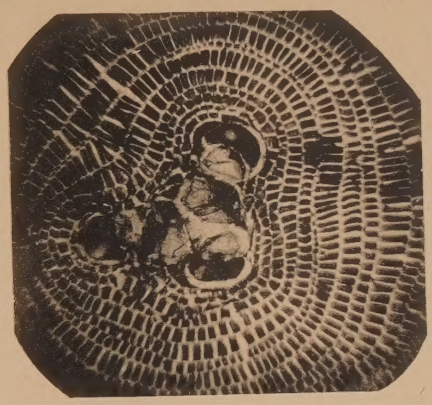
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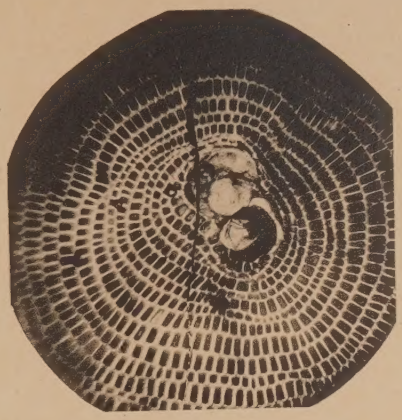
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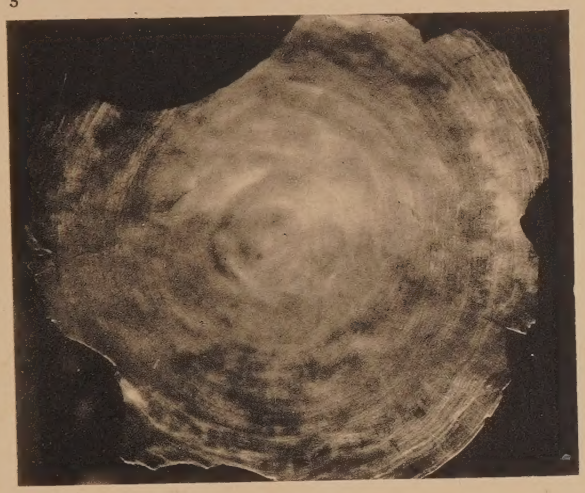
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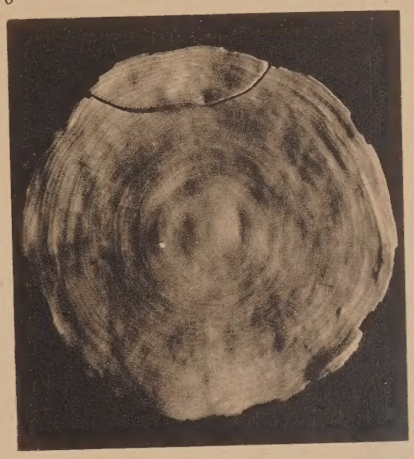
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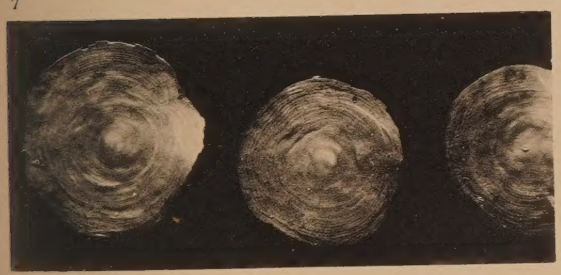
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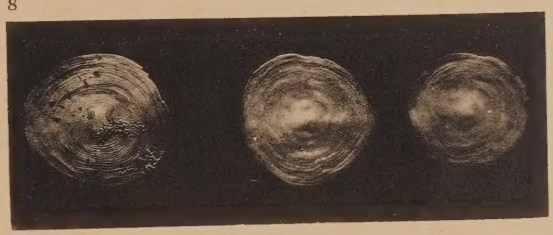
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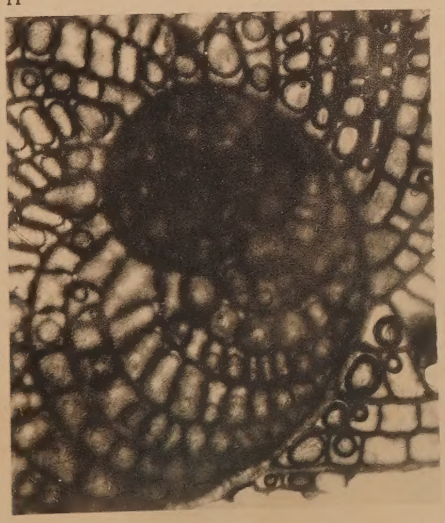
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J. HOFKER, PHOT.

HELIOTYPIE L. VAN LEER & Cº AMSTERDAM

HETEROSTEGINA AND CYCLOCLYPEUS.

THE FORAMINIFERA OF THE SIBOGA EXPEDITION

PART II

Families ASTRORHIZIDAE, RHIZAMMINIDAE, REOPHACIDAE, ANOMALINIDAE, PENEROPLIDAE

WITH AN INTRODUCTION ON THE LIFE-CYCLE OF THE FORAMINIFERA